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# Audiological correlates of aging

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**2015-01-16**
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# AUDIOLOGICAL CORRELATES OF AGING

*A dissertation submitted to the*

DEPARTMENT OF SPEECH PATHOLOGY AND AUDIOLOGY,

FACULTY OF ARTS,

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

in partial fulfilment of the requirements

for the degree of

MASTER OF ARTS IN AUDIOLOGY

by

LUCILLE PATRICIA DICKENS

JULY 1987.

*ERRATUM*

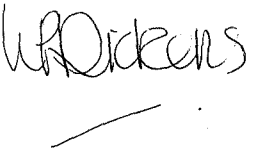
ADDITIONAL REFERENCE

HULL, R.H. (1981). *Demography and Characteristics of the Communicatively Impaired Elderly in the United States.* Seminars *in Speech, Language & Hearing*, 2/3: 138-144.

DECLARATION

I hereby declare that this dissertation represents my own work and has not been submitted to any other University.

SIGNED:



ACKNOWLEDGEMENTS

The writer expresses her thanks to the following people:

PROFESSOR M.L. ARON, for her help and guidance.

MS R.S. KEEN, for her advice and encouragement.

NEIL MORTON, for his help with the proofreading and printing of this report.

The subjects, without whom this study would not have been possible.

ABSTRACT

The effects of aging on various aspects of auditory function were examined. Age-related changes in threshold (pure tone and speech) and acoustic immitance measures were investigated for thirty-nine subjects ranging in age from sixty through to eighty-seven years. The characteristic audiometric configuration was seen and there was evidence of continuing sensitivity decline with increasing age. Speech thresholds were found to be in agreement with pure tone thresholds, and immittance values were within normal limits. Performance on three suprathreshold speech discrimination tasks, viz. CID W-22 word lists, the SPIN test and time-compressed SPIN material (CSPIN), was investigated and the effects of age and audiometric configuration were examined. Age was found to differentiate between the subjects while audiometric configuration did not prove to be a significant variable. Speechscore variation was significant for all the subjects (with the exception of the high predictability sections of the SPIN and CSPIN tests), indicating that different aspects of discrimination were being assessed. Context was seen to be an important factor in overcoming the distorting effects of both noise and time-compression. A strong relationship between audiometric measures and handicap, as reflected by the Hearing Handicap Inventory for the Elderly (HHIE), was not evident, although the low false-positive rate indicates that it may be a good measure to use in conjunction with pure tone screening for the identification of those elderly individuals who are in need of audiological services. The implications of the results are discussed.

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# CHAPTER I

## INTRODUCTION

> Man's adaptation to his environment is dependent to a large degree on his ability to express and receive verbal information. The earliest and most used sensory channel for this is the auditory system, embracing a highly complex set of interdependent functions, from perception through understanding (Bergman, 1985, p. 99).

Physical and sensory changes accompany the aging process, but many older individuals consider the difficulties that they experience with communication to be one of their major problems (Kasten, 1981). It is a recognised fact that hearing sensitivity declines with increasing age; hearing loss is one of the most common problems associated with aging (Nadol, 1981; Maurer and Rupp, 1979), and the changes in pure tone sensitivity that accompany aging have been well documented (e.g. Osterhammel and Osterhammel, 1979b; Corso, 1963; Hinchcliffe, 1962). However, hearing loss can only account for some, but not all, of the problems which the elderly experience with communication (Obler and Albert, 1981). Hearing impairment encompasses more than sensitivity loss and, in order to understand the auditory problems that are associated with aging, one needs to look at other factors in addition to the frequency and intensity descriptions of auditory performance (Bergman, 1985; Kasten, 1981).

There are many aspects of auditory processing in the elderly that are poorly understood (Marshall, 1981). However, a precise understanding of the changes that occur in auditory processing with aging, and determination of the strategies that the elderly employ

in the perception of speech, is necessary if the clinician is to effectively alter the conditions of the elderly individual's communicative interactions, in order to alleviate the disabling effects of the hearing impairment (Obler and Albert, 1981; Bergman, 1980). Thus the aim of this study was to investigate the effects of aging on various aspects of auditory function.

A perspective of the research concerned with hearing loss in the elderly is provided in Chapter Two. A general discussion of age-related problems is followed by a discussion of the anatomical and physiological changes that occur in the aging auditory system, studies which describe the effect of age on auditory function are reviewed, and the relationship between handicap and impairment is discussed. Details pertaining to the experimental procedure are outlined in Chapter Three, and the results are presented and discussed in the following chapter. The final chapter deals with clinical and research implications which arose from the results.

# CHAPTER 2

## BACKGROUND INFORMATION

> Aging is a dynamic series of biologic, social and psychologic changes (Garstecki, 1981, p. 261).

These changes can manifest as subtle problems or severe handicaps. Traditional theories on aging were based solely on biologic changes, while current theories tend towards social as well as biologic changes and a combination. Gerontology is an interdisciplinary science which encompasses all aspects of aging, including the physiologic, sociologic, psychologic, religious and political (Maurer and Rupp, 1979). Although scientists are not totally in agreement as to the cause of aging, there is a general consensus of opinion that more than time alone is involved (Birren and Renner, 1977, cited by Bergman, 1985). Aging varies greatly amongst and within species (Bergman, 1985) and it would appear to be a highly individualised process, with the variance found in this process unable to be accounted for by any one single theory (Maurer and Rupp, 1979).

Many chronic conditions such as high blood pressure, arthritis, heart disease and handicapping sensory deficits have been described as being associated with aging (Alpiner, 1965). The proportion of elderly individuals is on the increase (Bergman, 1985; Bentzen, 1981; Garstecki, 1981), consequently an understanding of these age-related problems, which need to be taken into consideration in the over-all rehabilitation process, is essential. According to

Harris (1977, cited by Maurer and Rupp, 1979), of the five most prevalent chronic conditions affecting the physical health of the elderly, hearing-impairment ranks second only to arthritis.

The descriptive term applied to hearing loss caused by physiologic aging is presbycusis. According to Maurer and Rupp (1979), presbycusis is not only the most common communicative problem amongst the elderly but it is also the most common hearing problem in the population as a whole. This auditory disorder manifests itself as a slowly progressive, bilaterally symmetrical, sloping sensori-neural loss, with speech discrimination skills which are poorer than would be expected for the degree of loss, especially in difficult listening situations (Møller, 1983; Willeford, 1978; Lowell and Paparella, 1979).

While the decrease in auditory function is coincident with biologic aging, it is not strictly related to aging alone. The study by Rosen, Bergman, Plester, El-Moffey and Salti (1962) can be seen to provide some support for this. These authors reported that the elderly Mbaans of the Sudan have better hearing acuity than their Western counterparts, and they attributed this to a difference in noise exposure. While exposure to noise may, or may not, be the primary cause of presbycusis, the current feeling is that the disorder is probably the cumulative effect of a number of disorders or insults which result in the degeneration of the auditory system (Nadol 1981; Schuknecht, 1974). Both social and biologic factors contribute to the aging process. Aging is primarily determined by genetic factors, but these are influenced by environmental factors,

such as diet, stress, etc., in addition to noise exposure (Cohn, 1981; Jerger and Jerger, 1981; Schuknecht, 1974).

## ANATOMICAL CHANGES

### Changes in the Peripheral Auditory System.

Presbycusis as a cause of hearing problems is not easily differentiated from other causes of progressive hearing loss such as, for example, the effects of ototoxic substances, hereditary factors, noise exposure or circulatory disorders. Furthermore, the possibility of the synergetic effect of any two or more of these cannot be ignored (Marshall, 1981; Cohn, 1981; Nadol, 1981). According to Arnst (1985) there is nothing pathognomic about presbycusis. Although it was originally thought to be caused by age related changes occurring primarily in the inner ear, more recent research suggests that the entire auditory system undergoes a wide range of senescent changes which can occur in many combinations (Arnst, 1985; Jerger and Jerger, 1981; Orchik, 1981). Physical examination of the ear and histopathologic studies give one an insight into the mechanism, although not the cause, of presbycusis.

### The external ear:

Major changes occur in the appearance of the ear. These may include decreased elasticity and increased size of the pinna, atrophy or increased flaccidity of the external auditory meatus and excess accumulation of cerumen (Jerger and Jerger, 1981; Wofford,

1981). These changes do not directly affect hearing, but the decrease in supportive tissue can result in the collapse of the ear canals with the pressure of the earphones, thereby creating a false conductive hearing loss (Arnst, 1985; Wofford, 1981; Hull, 1979).

The middle ear:

Many structural changes of the middle ear have been shown by histopathologic study. Thinning of the fibrous layers of the tympanic membrane (Wofford, 1981), thickening of the tympanic membrane (Jerger and Jerger, 1981) and fibrous and bony ankylosis of the ossicular joints (Mangham and Yarrington, 1984; Nadol, 1981) have been reported. Although these changes are not thought to be associated with detectable conductive hearing loss (Mangham and Yarrington, 1984), there have been reports of a high frequency conductive component (Milne, 1977, cited by Wofford, 1981; Rosen, Plester, El-Mofty and Rosen, 1964; Glorig and Davis, 1961). However, this may be accounted for on the basis of ear canal collapse (Randolph and Schow, 1983).

The inner ear:

The importance of senescent changes in the inner ear in relation to the characteristic high frequency hearing loss has been recognised for many years. Initially, two distinct areas of degeneration were noted, viz. atrophy of the basal end of the cochlea and stria vascularis (Arnst, 1985). Crowe, Guild and Polvogt (1934, cited by Maurer and Rupp, 1979) found that not all audiograms could be

matched with temporal bone findings, and suggested that the auditory nerve may be implicated as a site of presbycusis in certain cases. In 1955 Schuknecht reported that both epithelial and neural atrophy were signs of auditory aging, and Hansen and Reske-Nielsen (1965) reported an additional area of damage, i.e. vascular. In 1974 Schuknecht revised his original (1964) classification of presbycusis. Our present knowledge of the aged auditory system is primarily based on this classification, despite the fact that his work is based on case studies rather than on statistical analysis of data derived from large numbers of subjects (Marshall, 1981).

Schuknecht's (1974) classification system:

This system classifies the effects of aging on the auditory system into four main types.

1. Sensory presbycusis is manifested by degeneration and loss of hair cells and supporting cells. There is also secondary loss of cochlear neurons. The cause of the degeneration is unknown, but it was postulated that it may be related to lipofuscin accumulation in the cells and cochlear tissue. A high frequency, bilaterally symmetrical hearing loss with good speech discrimination is associated with this type.

2. Neural presbycusis is characterised by a loss of spiral ganglion cells and cochlear neurons and abnormalities of the myelin sheath. There may also be a loss of neurons in the higher auditory pathways. The hearing loss configuration is

similar to that found in sensory presbycusis, although hearing sensitivity as such may not be affected until the number of neurons falls below that required for effective transmission, integration and decoding. Speech discrimination is characteristically poor. According to Nadol (1981), this may be due to the greater need for neural integration for the encoding of speech signals in comparison with pure tones.

3. Metabolic/strial presbycusis is typified by atrophy of the stria vascularis, which is usually more severe in the apical and middle turns. Schuknecht postulated that the strial atrophy affects the chemical composition of the endolymph, which then has a detrimental influence on the metabolism of the secretory epithelium and, consequently, disturbs cochlear function and leads to hearing loss. The clinical feature is a flat, audiometric configuration and excellent speech discrimination.

4. Mechanical/cochlear conductive presbycusis is associated with a change in the mechanical properties of the cochlea. The resulting hearing loss is hypothesized to be the result of a disorder in the motion mechanism of the cochlear duct. The audiometric pattern is similar to that found for sensory presbycusis, and speech discrimination scores are inversely related to the steepness of the audiometric slope.

While this classification provides insight into presbycusis, there is a problem in that the patterns of degeneration discovered

through histopathologic analysis are not specific to any one etiological factor (Nadol, 1981) and it is not common for the disorder to manifest as a pure form (Cohn, 1981; Marshall, 1981). It is more likely that more than one type of anatomical degeneration may occur concurrently and, consequently, it is extremely difficult to classify the elderly as having a certain type of presbycusis on the basis of the audiometric findings.

Changes in the Central Auditory System

Schuknecht (1974), in his description of neural presbycusis, indicated that there may also be loss of neurons within the higher auditory pathways, but he did not elaborate on the central effects. Some investigators, e.g. Mangham and Young (1984) and Hinchcliffe (1962) have stated that central changes, i.e. those occurring within the brain, are mainly responsible for the audiologic picture of presbycusis.

Age related changes within all levels of the central auditory system have been reported. These changes can be viewed from a developmental/physiologic or involutional/pathologic point of view. The physiologic or developmental approach sees the changes that occur to be merely part of the normal ontogenetic cycle, with individual differences arising from the speed at which each individual passes through the cycle. Alternatively, the changes can be seen as pathologic and being the cumulative result of many diseases and insults (Valenstein, 1981; Smith and Sethi, 1975).

Currently both processes are thought to be involved in normal aging (Smith and Sethi, 1975).

Those changes that have been documented include: atrophy of the brain with reduced weight; reduction in the neuron population, the number of myelinated axons and the amount of white matter; altered brain metabolism; ventricular dilation; narrowed gyri; widened sulci; accumulation of fats and iron deposits in the central pathways; decreased cerebral bloodflow and cerebral oxygen consumption; and increased cerebrovascular resistance (Cohn, 1981; Jerger and Jerger, 1981; Valenstein, 1981; Maurer and Rupp, 1979; Antonelli, 1978; Smith and Sethi, 1975; Hansen and Reske-Nielsen, 1965). The changes occurring in the cortex appear to be unevenly distributed and are more pronounced than those in the ascending pathways; Hansen and Reske-N[illegible]sen (1965) reported that the changes in white matter are more [illegible] in the cortex, and an unequal rate of cortical attrition [illegible] the superior temporal gyrus appearing to have the greatest loss of neurons has also been reported (Valenstein, 1981; Brody, 1955, cited by Arnst, 1985).

Abnormal brain wave activity has been associated with aging. In more than a third of the elderly population there is some slowing of activity with focal slowing particularly over the anterior temporal lobe area, which is sometimes more pronounced for the left hemisphere (Smith and Sethi, 1975). This slowed activity, and the fact that nerve conduction velocity decreases with an increase in age (Smith and Sethi, 1975), may be the physiologic basis of the slowed central reaction time that has been reported for this

population (Bergman, 1985; Newman and Spitzer, 1983; Kasten, 1981; Maurer and Rupp, 1979; Smith and Sethi, 1975). Maurer and Rupp (1979) postulate that since the depleted neurons are not replaced by the division of the remaining cells, central auditory processing must become less efficient as the cell population declines. Thus the slowed neural conduction plus the less efficient central processing would mean that the elderly would require more time to deal with the incoming auditory signals. While this may explain the difficulty which the elderly have in understanding speech, particularly degraded speech (i.e. speech where the redundancy of the signal has been reduced in some way, for example, by means of filtering, time compression, etc.) and speech in noise, no link has yet been definitely established between the nature, extent and severity of the physical changes and the audiologic problems (Valenstein, 1981; Smith and Sethi, 1975).

## EFFECT OF AGE ON AUDITORY FUNCTION

### Pure Tone Sensitivity.

#### Air and bone conduction thresholds:

While the exact relationship between histopathologic findings and audiologic manifestations may not have been established, the fact that hearing sensitivity declines with increasing age has been known for a long time. Zwaardemaker (1899) is generally cited as the first person to investigate and document the age-related, gradually sloping, high frequency hearing loss and to coin the term

'presbycusis' (Arnst, 1985; Bergman, 1985; Møller, 1983; Lowell and Paparella, 1977). This decrease in pure tone sensitivity is probably the most widely examined aspect of presbycusis and, since the development of the pure tone audiometer, many reports concerning the audiometric configuration have appeared which lend support to Zwaardemaker's original description (e.g. Møller, 1983; Osterhammel and Osterhammel, 1979a; Corso, 1963).

Although the loss has mainly been described as being sensorineural, some changes in the bone conduction response have also been reported. Carhart (1958, cited by Orchick, 1981) described the Bernero effect, i.e. a greater loss by bone conduction than by air conduction at 500 Hz. He attributed this to a central dysfunction, but Melrose, Welsh and Luterman (1963) felt that the more likely explanation was that it was a reflection of alterations in the impedance of the skull. Discrepancies concerning the presence or absence of a conductive component are also noted. A few studies (e.g. Milne, 1977, cited by Wofford, 1981; Nixon, Glorig and High, 1962; Glorig and Davis, 1961) reported the presence of a high frequency air-bone gap which was related to pathologic changes in the middle ear. However, Randolph and Schow (1983) attribute this reported air-bone discrepancy to collapsed canals.

Sex differences:

There appears to be some disagreement concerning the effect of sex on age-related sensitivity decline. Corso (1963) stated that the hearing loss for men is slightly greater than that for women.

Spoor (1967) examined the data on age-related changes in hearing from eight different studies, including the one of Corso, and concluded that the thresholds for males are definitely higher than for females, and Jerger and Jerger (1981) contend, on the basis of clinical experience, that the pattern of presbycusis differs between the sexes. However, others feel that the reported sex difference arises from a difference in noise exposure, and not sex per se (Møller, 1983; Osterhammel and Osterhammel, 1979a).

In addition, the contribution of factors other than normal aging to the hearing loss may compound the issue. Lowell and Paparella (1977) suggested that presbycusis, where the hearing loss is solely attributed to age and where there are no contaminating genetic or environmental factors, is rare. The Rosen et al study (1962) would seem to support the idea of more than biologic aging contributing to the hearing loss. In addition, it also provides support for a sex difference, since it highlighted a difference in hearing threshold for men and women. However, Møller (1983) criticises this study on two counts: firstly, not many subjects actually knew their age and were judged to be of a certain age by Rosen and his associates on the basis of their appearance and, secondly, only a few of their subjects were in the older (above 70) age group. Consequently, she questions their conclusions and states that direct comparison with studies conducted in the West is not possible. The question of sex differences could only be resolved if the differential effect were investigated in that rare group of individuals who would conform to Lowell and Paparella's criteria for being classified as presbycutic. However, differentiation of

hearing loss due to aging only is a purely theoretical concept, since it is difficult to distinguish the effects of endogenic and exogenic factors from those of age (Cohn, 1981; Hull, 1978). Furthermore, this would merely be an academic exercise because, as Bergman (1985) says, the important factor is the actual loss, regardless of the relative contributions of presbycusis, sociocusis, nosocusis, genetic, racial or other factors.

Continuing sensitivity decline:

Another area of disagreement is that of continuing sensitivity decline. Some investigators report that thresholds plateau after a certain age (Sataloff et al, 1957; Melrose et al, 1963), while others have found that sensitivity continues to decline with increasing age (Corso, 1963; Goetzinger, Proud, Dirks and Embrey, 1961). A longitudinal study conducted by Møller (1981, cited by Møller, 1983) clearly demonstrates that hearing does continue to decline with increasing age for subjects tested at 70 years and again five years later. If a plateauing does indeed exist, this must therefore occur after 75 years of age.

Reception and Discrimination of Speech.

Reception thresholds:

For young listeners, the threshold for speech (SRT) typically correlates well with the pure tone average (PTA) score. Except for some of the subjects in Pestalozza and Shore's (1955) study, this relationship has not been reported to be altered although, as would be

expected, the mean SRT value for older individuals is elevated in comparison with that of normal hearing young listeners (Punch and McConnell, 1969, cited by Corso, 1977). Of more interest is the effect of age on speech discrimination abilities. This area has received considerable attention and, after reduced hearing sensitivity for deterioration of speech discrimination, is the most commonly recognised feature of presbycusis.

Speech discrimination in quiet:

Gaeth (1948) is cited by most researchers as being the first person to describe the discrimination problems experienced by the elderly (Hayes, 1984; Moller, 1983; Orchik, 1981; Willeford, 1978). He reported that discrimination scores are poorer than would be predicted from the pure tone audiogram, and he called this phenomenon 'phonemic regression'. Subsequent research by Pestalozza and Shore (1955) supported the concept of phonemic regression. By comparing the speech discrimination socres obtained by young and elderly subjects, matched with regard to pure tone audiograms, they found that the young subjects' scores were approximately 20% better. Goetzinger et al (1961) and Luterman, Welsh and Melrose (1966) also demonstrated reduced discrimination scores for the elderly, which they attributed to changes occurring within the central auditory system.

A problem with these early studies is that discrimination was only assessed at one presentation level. Kasden (1970) noted that maximum discrimination scores for the elderly tended to be reached at

higher presentation levels than for young listeners. Consequently, if discrimination is being sampled at only one audiometric level, and the performance of the elderly is compared with that of young listeners, the actual discrimination abilities of the elderly subjects may be underestimated. Møller (1983) also criticises these studies on the grounds that the data was collected from elderly subjects who had been referred to a speech and hearing clinic because they were experiencing problems. The results which she obtained from an unselected group of old people were rather different (1981, cited by Møller, 1983). The mean discrimination scores (93% for females and 86% for males) for randomly selected, elderly individuals were higher than those previously reported, and were in agreement with what would be predicted on the basis of the pure tone audiogram. The distribution of the scores indicated that 75% of the females and 50% of the males had scores better than, or equal to, 92%. She concluded that discrimination in the elderly is not noticeably more reduced than that for young people, and that the data do not provide much support for the concept of central auditory disturbances being prevalent amongst the elderly. Similar results were reported in an earlier study by Klein (1976). She investigated discrimination abilities in two groups of elderly individuals; one group containing subjects who had been referred to a speech and hearing clinic, and a matched group of subjects who had not previously complained of hearing problems, and found generally poorer performance for the clinic cases. However, in contrast to Møller, she reported that the discrimination abilities were poor for both groups.

Other studies have also rejected the concept of poorer discrimination abilities being characteristic of age-related changes in auditory function (Surr, 1977, cited by Marshall, 1981; Kasden, 1970; Harbert, Young and Menduke, 1966). In these studies, these investigators carefully matched the audiograms of young listeners to those of elderly subjects, and did not show any difference between the groups, concluding that discrimination abilities are influenced by degree of loss, and not age. However, the results of a study conducted by Bess and Townsend (1977) indicated that discrimination abilities are probably affected by the interaction of age and degree of loss. They found that subjects with PTA scores of less than 49 dB did not show much of an age effect, while those with a greater degree of hearing loss showed a definite age effect, which seemed to increase with the severity of the loss.

From this discussion it becomes evident that the combined influences of increasing age and degree of loss need to be further investigated. The effect of the configuration of the loss also warrants attention, since a strong relationship between this aspect and speech discrimination has been reported (Dirks and Dubno, 1984; Dubno and Dirks, 1982), although this has not been specifically investigated in the elderly population.

Speech discrimination in noise:

Most real-life communication occurs in the presence of background noise. Consequently, in order to describe the discrimination problems which the elderly experience, this needs to be examined in

less than ideal conditions. Smith and Prather (1971) reported that the elderly, in comparison with young listeners, show reduced discrimination for nonsense syllables in the presence of broad band noise at various signal-to-noise (S/N) ratios. Orchik and Burgess (1977), cited by Orchik (1981), examined synthetic sentence identification (SSI) in the presence of ipsilateral competing messages (SSI-ICM) as a function of aging, and found significantly poorer performance for the elderly. Since all their subjects had normal peripheral hearing, they concluded that this reflected a central effect. A discrepancy between maximum discrimination scores for CID W-22 words presented in quiet and maximum SSI scores (at 0 dB S/N ratio), which follows the same pattern observed in young listeners with documented central auditory dysfunction, was seen by Jerger and Hayes (1977) in elderly individuals. They noted that this effect was not related to any particular audiometric configuration and, thus, felt that it reinforced the idea of a central effect.

The effect of noise on the reception of real sentences was investigated by Plomp and Mimpen (1979a) and Duquesnoy (1983). They found that the problems which the elderly experience primarily manifest themselves in noisy conditions, and that noise has a differential effect even amongst individuals with similar hearing loss. Plomp and Mimpen (1979a) plotted the median hearing loss for speech for the different age groups as a function of the Fletcher index, and as a result of this analysis they concluded, in contrast to Orchik and Burgess and Jerger and Hayes, that for subjects up to about 90 years the speech problems are due to deterioration of the

auditory pathways, rather than to central processing problems. They used real Dutch sentences as stimuli because they considered them to be more representative of everyday listening situations, in contrast to synthetic sentences which are devoid of the supra-segmental and contextual cues which are normally available for perception in conversational speech. The stimuli differ in terms of the amount of redundancy and, therefore, the degree to which the central processing system is stressed when they are presented in noise would also differ.

A test which contained both high and low redundancy items would be more suitable for assessing the problems which the elderly experience when speech is presented against a background of noise. Such a test is the Speech Perception in Noise (SPIN) test, which was developed by Kalikow, Stevens and Elliott in 1977. These researchers recognised that in speech communication adults utilize acoustic-phonetic and linguistic-contextual information for perception. The SPIN test comprises eight lists of 50 sentences each, where the predictability of the final target word of each sentence is controlled. Half the items in each list are designed to be identified primarly by acoustic-phonetic information (low predictability [LP]) and the other half are designed so that linguistic-contextual information is present to aid identification (high predictability [HP]). Examples of each of these sentence types are: "The beer drinkers raised their mugs" (HP), and "Peter should speak about the mugs" (LP). Each test word is presented in both an HP and an LP context in complementary lists.

The sentences are presented in a 12-voice background babble, both being recorded on separate channels of audio tape to allow variation of the signal-to-babble (i.e. the S/N) ratio. The test thus examines discrimination as a function of both context and competing noise, and research has established that, as would be expected, the performance of normal hearing young adults improves when contextual cues are present and the noise level is decreased (Dickens and Delaney, 1986; Owen, 1981; Kalikow et al, 1977). Since Dickens and Delaney (1986) found that scores were better at a lower presentation level, regardless of S/N ratio, both factors (i.e. S/N ratio and presentation level) need to be considered when describing the elderly's discrimination in noise.

Kalikow et al (1977) found that the difference scores (i.e. HP-LP) of ten elderly subjects were slightly depressed relative to those of younger listeners. Owen (1981) found that an elderly (mean age =.52 years) group differed from a group of hearing impaired children (mean age 9,5 years) primarily with regard to LP scores. The poorer scores obtained by the elderly subjects could not be accounted for on the basis of hearing sensitivity since this group had a better mean PTA score. He therefore concluded that central processing factors accounted for the smaller LP scores, and suggested that it may be possible to use the LP sentences as a measure of central processing. The performance of aged subjects on the SPIN test in general, and specifically the use of LP scores as an index of central auditory involvement, needs to be examined in more detail.

Time-compressed Speech.

Central auditory processing can be considered a special kind of speech discrimination (Willeford, 1978), and research has suggested that reduced function of the central auditory nervous system (CANS) becomes evident when the speech is degraded or desensitized in some manner. In addition many studies have indicated that the elderly experience difficulty in processing sensitized speech (e.g. Bergman, 1983; Clarke and Knowles, 1973; Bergman, Blumenfeld, Cascardo, Dash, Levitt and Margulies, 1976; Bergman, 1971; etc). This reduction in the ability to understand distorted speech is thought to be related to temporal processing abilities, i.e. the elderly require an increased time constraint for perceptual processing (Bergman, 1985; Antonelli, 1978).

Speech can be described as being composed of variations in frequency, intensity and time (Kasten, 1981), and can be distorted by manipulation of any of these parameters. Possibly because the problems that the elderly experience are thought to be temporally related, this is one area which has received much attention. While the exact nature of the temporal processing of speech and language is not known (Kasten, 1981), interest in time as a factor in age-related problems in speech understanding has grown considerably over the last years. This interest dates back to an early report by Calearo and Lazzaroni (1957) which documented the difficulty experienced by the aged, when compared with young listeners, in responding to fast speech. They concluded that the central acoustic reaction time was lengthened as a result of the

aging process. Since this report many others have appeared, but not all studies are in agreement.

Temporally related alteration has been accomplished by a change in speech rate (Calearo and Lazzaroni, 1957), by interruption (Moller, 1983; Bergman et al, 1976) and more frequently by expansion and compression (Korabic, Freeman and Church, 1978; Konkle, Beasley and Bess, 1977; Schon, 1970; etc). While the simplest method of altering the temporal characteristics of speech is to merely speak faster, there are a number of drawbacks to this. The major advantage of not requiring any special instrumentation is outweighed by the fact that the speaker tends to introduce undesirable changes in the spectral qualities, and that there is a physiological limitation to the amount by which the speaker can shift the rate (Beasley and Maki, 1976). Furthermore, there is no means of precisely controlling the rate. A more precise method used in some studies was to change the playback speed of a pre-recorded signal on a tape recorder (Beasley and Freeman, 1977). However, this also results in undesirable shifts in the frequency of the signal which are proportional to the playback speed (Rintelmann, 1985; Beasley and Freeman, 1977). Garven in 1953 (cited by Beasley and Maki, 1976) used a manual sampling technique which partially eliminated the problems with frequency shifts, but was not efficient because it was laborious and time-consuming.

The first electromechanical time compressor/expander was developed in 1954 by Fairbanks, Everitt and Jaeger (cited by Rintelmann, 1985; Beasley and Maki, 1976). This device made use of a tape loop, passing over an assembly of rotating heads, which received

the signal to be altered. The segments of the tape loop touched by the heads were transferred to a storage tape recorder. In this way segments of the original tape would be sampled and recorded, while other sections would be discarded. The degree of compression/expansion was determined by the relative velocity of the tape loop and the rotation speed of the head assembly. The retained portions of the signal were electromechanically abutted so that there were no silent intervals within words. This method, unlike Garvey's manual sampling technique, does not allow control over which segments of the original message are retained; the sampling is random. Lee (1972, cited by Beasley and Maki, 1976) modified this equipment and developed a smaller, less expensive compressor known as the Varispeech. This equipment is still currently used, and compressed speech has become a quick and relatively simple means of assessing central auditory function.

Normative data is necessary in order to use time-altered speech to assess auditory processing. Although this has been generated in a series of studies, no universal norms have emerged since the studies varied extensively with respect to the type of stimulus used, the rate of compression/expansion, and the presentation level. In spite of this, some generalisations can be drawn from the studies concerned. Beasley, Schwimmer and Rintelmann (1972) found that normal hearing young adults' discrimination of monosyllabic words decreased as the rate of compression increased, and that as the sensation level increased there was an increase in intelligibility. These findings substantiated the earlier reports of Luterman, Welsh and Melrose (1966) and Sticht and Gray (1969),

who found similar trends based on small samples of subjects. The essential feature that emerged from these and other studies (e.g. Beasley, Bratt and Rintelmann, 1980) was that the compression rate at which intelligibility is affected depends on both the type of speech stimulus used, and the presentation level. This serves to highlight the importance of establishing norms for each investigation.

The effects of time-expansion on speech recognition scores in normal-hearing young adults has been less widely studied, but the results would seem to indicate that expansion over a large range (i.e. up to 100%) has little effect on performance (Korabic et al, 1978; Schon, 1970; Luterman et al, 1966).

There is disagreement about the effects of time-alteration on speech recognition in the elderly. Sticht and Gray (1969) used a limited number of stimuli (15 CID W-22 words) to investigate perception of time-compressed speech for a small group of elderly subjects with normal hearing. They found that the elderly had reduced scores in comparison with a group of normal-hearing young adults. This deterioration in performance for the elderly group, who apparently showed no audiometric signs of presbycusis, prompted these authors to state that presbycusis per se is not a necessary condition for compression to disrupt performance. They observed a similar age effect when comparing elderly hearing impaired subjects with a matched group of young adults with sensorineural hearing impairment. They concluded that the disruptive effects of time-compression are of central, rather than

peripheral origin. The results of this study were contradictory to those reported in an earlier study by Luterman et al (1966). They found no difference between three groups of subjects (normal hearing young subjects, hearing impaired elderly subjects, and a group of young subjects within sensorineural hearing losses matched to those of the elderly subjects) in their ability to recognise time-altered speech. A criticism of this study is that the rates of compression used (10% and 20%) may not have been sufficient to differentiate between the groups. Schon (1977) examined performance for time-compressed CID (Central Institute for the Deaf) sentences of four groups of male subjects; normal hearing and hearing-impaired, and young and old. He found similar performance for both elderly groups and the young hearing-impaired group. Since he had used a less stringent criterion for normal hearing in the elderly group than that applied by Sticht and Gray, all the subjects, with the exception of the group of normal hearing young subjects, had some degree of loss at 3000 Hz. Schon, therefore, concluded that the poorer performance may be a feature of the hearing loss and not age. In support of this he cites Harris (1960), who indicated that 3000 Hz may be a critical factor in the discrimination of rapid speech. However, further support for the age-effect can be found in the study by Konkle et al (1977). Using four groups of subjects ranging in age from 54 to 84 years, all having normal hearing and at least 90% discrimination scores for Northwestern University (NU6) word lists, they demonstrated a significant compression by age interaction. Intelligibility decreased as a function of increasing time-compression and age, and also as a function of decreasing sensation level. Since all

subjects had comparable scores for the 0% condition, they concluded that the difficulty experienced with increasing age reflected changes in the central, rather than the peripheral, auditory mechanism, i.e. the changes were a function of the neural degeneration in the higher central nervous system, regardless of concommitant peripherally based loss.

Beasley et al (1980) presented time-compressed sentential stimuli to normal hearing young adults and found that these were nearly as sensitive to the effects of time compression as monosylliabic words. They suggested that time-compressed sentences could be useful in evaluating central auditory function in patients with concommitant peripheral hearing loss. However, research examining comprehension of time-altered sentences in the elderly has not indicated any specific trend of results. Schmitt and McCroskey (1981) and McCroskey and Schmitt (1978, cited by McCroskey, 1979) found that elderly listeners responded similarly to time-compressed (60%) and time-expanded (140%) sentences presented in a multiple choice format, i.e. comprehension improved for both compression and expansion over the condition where speech was not time-altered, but with further expansion (to 180%) performance deteriorated. Further research by Schmitt (1983) showed that young-old subjects (65 to 74 years) performed differently to old-old subjects (75 to 84 years) on passages of speech and questions that had been rate altered. The younger group showed improved performance at both 140% and 180% expansion, while the older group's performance deteriorated at 180%, after having improved at 140%. Performance for both groups was poorer for the compressed condition.

Thus, in conclusion, it can be seen that the research findings concerning the elderly individual's performance on time-altered speech is equivocal. There is the possibility that an age/degree of hearing loss interaction, which has not been examined, is contributing to the lack of agreement between studies. Another contributing factor may be related to the diverse nature of the stimuli used. While the majority of studies utilised monosyllabic words, the research by Beasley et al (1980) indicates that sentential stimuli would be preferable in view of the increased likelihood of peripheral involvement in the elderly. According to Beasley and Maki (1976), an important consideration is whether the data reflects upon intelligibility or comprehension. Monosyllabic stimuli provide information pertaining to intelligibility, but may be inadequate for assessing the linguistic integrity of the central processing system. By using material which combines both monosyllabic and sentential features, such as the SPIN, both these aspects could be investigated. This would also allow comparison of the effects of noise and time-alteration on speech discrimination.

Acoustic Immittance.

Immittance is the term used to encompass both impedance and admittance measurements, impedance referring to the opposition of the energy flow, and admittance referring to ease of energy flow at the tympanic membrane (McCandless, 1979).

The immittance test battery is an essential part of the basic audiological assessment procedure, yet the effect of aging on these results is not clearly understood.

Tympanometry and static compliance measures:

Not much is known about how the aging process may affect the tympanogram (Orchik, 1981), although Jerger and Jerger (1981) have reported that impedance audiometry usually yields normal type A tympanograms. However, there is some disagreement concerning the static compliance values recorded from the elderly. Jerger, Jerger and Mauldin (1972) report a systematic decline in static compliance with increasing age, which is particularly evident in men, with women at each age level consistently having lower compliance values than men. In agreement with these results, Alberti and Kristensen (1972, as cited by Marshall, 1981) state that up until middle age the middle ear system becomes increasingly compliant, and thereafter it stiffens with further aging. In contrast, Beattie and Leamy (1975, as cited by Wofford, 1981) found that otoadmittance is significantly increased in the elderly. Osterhammel and Osterhammel (1979b) collected normative data from 286 subjects ranging in age from 10 to older than 70, and found that static compliance values did not show a statistical difference between males and females, and no real age effect was seen, although they did report a statistically nonsignificant tendency for compliance values to decrease with an increase in age. Other studies (Wilson, 1981; Thompson, Sils, Recke and Bui, 1979) have also shown no immittance changes as a function of aging. Thompson et al (1979) conclude that inconsistencies between studies may be due to differences in experimental design and other factors, and that the effect(s) of age on immittance is complex. From these studies it becomes apparent that results from different studies should be

compared with caution, and that, at present, there is no universal norm for the elderly group.

Acoustic reflex thresholds:

There is further lack of agreement between the researchers about the effect of age on the acoustic reflex thresholds. Jerger, Hayes, Anthony and Mauldin (1978) found a systematic decrease in acoustic reflex thresholds (ARTs) for pure tones with an increase in age, and no change in acoustic reflex threshold for broadband noise (BBN). Wilson (1981) reported higher tonal ARTs for his elderly subjects, but the difference was not significant. However, he did find, in contrast to the Jerger et al (1978) report, significantly higher BBN ARTs for this group. Other studies have confirmed that age does not affect the pure tone ARTs (Gelfand and Piper, 1981; Osterhammel and Osterhammel, 1979b; Silman, 1979) and that the ART for BBN is elevated with increasing age (Gelfand and Piper, 1981; Silman, 1979), but Thompson, Sils, Recke and Bui (1980) found no changes in ARTs for either pure tones OR filtered white noise, but did find reduced reflex amplitude with increasing age. This smaller reflex magnitude for both tone and BBN was also reported by Wilson (1981) and Hall (1985; 1982). According to Wilson, this may be due to

> ... general decrease in the efficiency of neurophysiological activity throughout the acoustic-reflex arc from the sensory/ neural mechanisms of the stimulus ear to the neural innervation of the stapedius muscle in the proble ear (p. 413).

The preceding studies are mainly concerned with the effects of age

on the ART. Jerger et al (1978) also investigated the interaction of age and hearing loss (degree and configuration; *sloping/flat*) on the ART. A similar age/degree of hearing loss interaction, as seen by Bess and Townsend (1977) for speech discrimination scores, was found. Age interacts with degree of loss, i.e. generally for all stimuli there is little age effect for the 0-50 dB PTA range, but for higher PTAs there is a definite age effect. The age effect is always in the same direction; at equivalent PTAs the ART for children is consistently higher than that for young adults which, in turn, is higher than that for old adults. Configuration was not found to be a significant variable.

While the research thus indicates that the ART is affected by aging, the exact way in which it is affected is not clear, i.e. whether tonal ARTs are reduced, or whether BBN ARTs are *elevated, and what the age/hearing* loss interaction is. The effects of age on the ART need to be investigated further.

## HEARING HANDICAP IN THE ELDERLY

Due to recent advances in medical science and modern technology, the number of aged persons in society is increasing steadily (Hull, 1978; Willeford, 1978). Although people may be living longer, this does not mean that the aging process has been reversed. Many chronic conditions, of which hearing impairment is one of the most common, are associated with aging (Garstecki, 1981; Maurer and Rupp, 1979; Alpiner, 1965). The fact that the elderly population is constantly increasing thus suggests that many elderly indivi-

duals would be hearing impaired and have the need of audiological services. However, Ventry and Weinstein (1983) state that few of the elderly actually make use of audiological services, in spite of the fact that many may actually benefit from these. Consequently, there is a need to identify those elderly individuals who have hearing problems. Some of the negative side effects of aging, such as social isolation and increased dependency, may be alleviated if auditory skills are improved, which, in turn, could result in restoring the geriatric patient's self-esteem (Willeford, 1978).

Hearing Impairment and Hearing Handicap.

In order to successfully identify those individuals with hearing problems, so that audiological assistance can be provided, it is necessary to differentiate between hearing impairment and hearing handicap.

Traditionally, these terms have been incorrectly used as synonyms (American Speech-Language-Hearing Association, 1981). The extent of communication problems and need for amplification have, in the past, been assessed through the use of the PTA score (Freeman and Sinclair, 1981). While audiometry and, therefore, the PTA score may define the extent of the loss, the handicap is determined by the communication deficit and the associated problems (Oyer and Frankman, 1976, as cited by Freeman and Sinclair, 1981). According to the American Speech-Language-Hearing Association, hearing impairment is the term

> ... used to mean a deviation or change for the worse in either auditory structure or function, usually outside the range of normal ...

and hearing handicap

> ... means the disadvantage imposed by a hearing impairment on a person's communicative performance in the activities of daily living ... (p. 293).

While there is a definite relationship between loss and handicap, this relationship is imperfect (Ventry and Weinstein, 1983).

Research by Koniditsiotis (1971) into the relationship between audiometric data and actual performance showed that there was a good relationship between sensitivity measures and handicap, and she concluded that hearing sensitivity is the best indicator of hearing handicap. However, her research was limited in that she only used nine subjects, and her final conclusion is one that is not shared by the majority of researchers.

The interaction of many factors determines the degree to which a loss becomes handicapping, e.g. age of the individual and age of onset of the loss, his communicative needs, intelligence, motivation, etc (Clark, 1981; ASHA, 1981). Consequently, when assessing the elderly, one needs to not only focus on the audiologic data but also on the communication breakdown that may be caused by the auditory deficit (Alpiner, 1982; 1981). The PTA alone cannot predict handicap (Ventry and Weinstein, 1983) and so, over the years, a number of assessment tools to measure handicap have been developed.

Measurement of Handicap.

In an attempt to quantify handicap, Davis (1948) developed the

Social Adequacy Index (SAI) which was based on the relationship between SRT and discrimination scores. However, it was not very effective, primarily because of the reliance on numeric data which tends to obscure individual behavioural characteristics (Alpiner, 1982). Following this, a number of scales were developed which can be classified as being either a tool for the identification of hearing handicap or to be used for rehabilitative purposes. Of those designed specifically for use in the rehabilitative process, some investigated situational difficulties relating to the social, home and vocational environments (Sanders, 1975), while others, e.g. the Denver Scale (Alpiner, Chevrette, Glascoe, Metz and Olsen, 1975, cited by Alpiner, 1982), and the McCarthy-Alpiner Scale of Hearing Handicap (McCarthy and Alpiner, 1980, cited by Alpiner, 1982) explored the emotional and attitudinal effects of the loss. These scales were not specifically designed for use with the elderly. Although Zarnoch and Alpiner (1977, cited by Alpiner, 1982) developed a scale for use with the elderly living in old age homes, the primary focus of it was to provide information to direct rehabilitation, rather than on the identification of hearing handicap.

The Hearing Handicap Scale - HHS (High, Fairbanks and Glorig, 1964), is an example of the type of scale which has been used to identify hearing handicap. It was designed to assess the effects of hearing loss on an individual's life. However, a study by the authors indicated that better ear hearing sensitivity appears to be the major determinant of hearing handicap as measured by the HHS, with a negligible relationship between speech discrimination (scores on the CID W-22 and Rhyme test administered at 40 dB SL)

and the HHS. Subsequent research has confirmed this. Blumenfeld, Bergman and Milner (1969) used the HHS to investigate the relationship between handicap and discrimination in quiet and in noise (Rhyme test) as a function of aging. They found a moderate correlation between the Rhyme test and the HHS, which was better for the older subjects (60-82 years) than for younger subjects. However, Berkowitz and Hochberg (1971) investigated the relationship between the HHS and various audiometric measures for 100 presbyacutic subjects ranging in age from 60 to 87 years, and found that while the HHS and the PTA, SRT and word and sentence discrimination were significantly related for the 60-69 year old group, this relationship disappeared for the older subjects (for those in the 70-79 year group the HHS and PTA and SRT correlated; while for the group aged 80 and above there was no significant correlation). According to Giolas (1970), the major limitation of the HHS lies in its inflexibility. He states that item analysis indicates that the majority strongly depend on hearing sensitivity, which would explain the good correlation between it and PTA and SRT measures, and suggested that it may not be a full measure of handicap, and that more items dealing with difficulties with speech hearing need to be included.

The Hearing Measurement Scale (HMS) (Noble, 1972; Noble and Atherly, 1970) was designed specifically to assess handicap caused by noise induced hearing losses. The authors found that while there was a fairly good correlation between the section on speech hearing and speech discrimination scores, the scale as a whole did not correlate well with suprathreshold speech tests. Weinstein and

Ventry (1983) investigated the relationship between the HMS and audiometric measures in 80 elderly male Ss. They found that each of the correlations between the measures of sensitivity and the HMS were significant. The HMS/speech discrimination correlation was lower than that for the pure tones and, consequently, they concluded that the HMS is sensitivity weighted and, therefore, is not unlike the HHS in content. Maurer and Rupp (1979) and McCartney, Maurer and Sorenson (1976) have suggested that a scale more sensitive to handicap may be constructed by combining questions from the HHS and the HMS.

Tyler and Smith (1983) reported a good correlation between the HMS and the Social Hearing Handicap Index (SHI) developed by Ewertson and Birk Nielsen (1973), as well as a good correlation between both these scales and sentence identification in noise, suggesting that both could be used to quantify handicap. However, a major problem with these and most other scales is that they were not developed for, nor standardised on, the elderly population.

A short, 16-item questionnaire, devised specifically for the elderly and aimed at identifying individuals needing audiological services, was developed by Manzella and Taigman (1980, cited by Alpiner, 1982). According to these authors, three or more positive answers (indicating difficulty) was indicative of a hearing loss of 40 dB or more in the better ear. The relationship between this scale and speech discrimination has not been investigated, so presently it is unknown whether it, like other hearing handicap scales, may have a good correlation with PTA but have little

relationship with the difficulties which the individual may have in understanding speech.

Another scale which was designed for, and standardised on, the elderly is the Hearing Handicap Inventory for the Elderly (HHIE) (Ventry and Weinstein, 1983). In addition to the standard HHIE, a screening version was also developed. The items for this were selected in such a way that the reliability of the short form is comparable with that of the full inventory. There are ten items, which are designed to assess both social and emotional aspects of handicap, and which are awarded 4 points (yes, implying that the individual agrees with the statement and experiences difficulty), 2 points (statement applies sometimes), or 0 (indicating no difficulty). On the basis of the score out of 40, three categories of handicap can be identified: 0-8, no self-perceived handicap; 10-22, mild to moderate handicap, and 24-40, significant handicap. These authors investigated the accuracy of the screening version of the HHIE and recommend that a combination of puretone screening (40 dB at 1 and 2 kHz) and the short version of the HHIE be used, in order to identify those individuals in need of further evaluation. This is determined according to a priority system:

Priority 1 - significant handicap and fails pure tone screening.

Priority 2 - significant handicap and passes pure tone test.

Priority 3 - mild handicap and fails pure tone test (Ventry and Weinstein believe that these three categories deserve essentially the same priority).

Priority 4 - mild handicap and passes pure tone test, and

Priority 5 - no handicap and fails pure tone screen.

While this would appear to be a viable means of identifying those individuals with hearing loss and/or handicap, Ventry and Weinstein have pointed out the need to investigate the validity of the screening protocol and the priority system by examining false-negative and false-positive referral rate. Thus, one of the aims of this study was to investigate the validity of the HHIE by administering it to each subject prior to conducting a complete audiological assessment. In addition, it was decided to examine the relationship between the HHIE and certain speech tests (an issue not addressed by Ventry and Weinstein), in order to determine whether there is a better relationship between it and speech identification than was found for other scales.

# CHAPTER 3

## METHODOLOGY

In reviewing the research on the effects of aging on hearing, it becomes evident that the previous use of the term presbycusis has perhaps been too simplistic. In particular, the generalised application of certain concepts, e.g. the use of the term "phonemic regression" to explain the poor speech discrimination observed in some elderly individuals, needs to be reassessed. In order to improve the services provided to the elderly, the clinical audiologist requires a better understanding of the various effects of aging on auditory behaviour and communication ability. Continuing research and evaluation of the interactive effects of age and hearing should improve this understanding, and the present study was thus designed to contribute towards this.

## AIMS

The aim of this study was to examine the effects of aging on various aspects of auditory function in a group of elderly individuals. The specific aims were:

1. To examine age-related changes in threshold (pure tone and speech) measures.

2. To examine age-related changes in acoustic immittance measures.

3. To investigate performance of the elderly on three supra-threshold speech discrimination tasks, viz. CID W-22 word

lists, the SPIN test, and time-compressed SPIN material (CSPIN), and to examine the differential effect of age as opposed to audiogram configuration on speech discrimination.

4. To examine the relationship between audiometric measures and handicap as reflected by the Hearing Handicap Inventory for the Elderly.

SUBJECTS

Subjects (Ss) were selected from five residential institutions for the elderly in the Cape Town area. These were chosen on the basis of proximity to the University of Cape Town, where testing took place.

At each institution the matron or sister-in-charge pre-selected Ss according to certain criteria. These were:

1. Age: All Ss were required to be 60 years or older. While the effects of age may well be seen quite clearly in life, 60 was considered to be a reasonable lower limit, since Marshall (1981) reports that in most studies the elderly are defined as being 60 or older. No upper restriction on age was made.

2. Home Language: English was required to be the native language of all Ss since speech testing would be conducted in this language and unfamiliarity with the language could affect performance.

3. Mobility: Ss were required to be normally active, and not

bed-ridden or confined to a wheelchair. This was a necessary restriction because Ss had to be transported to the University clinic where testing took place.

4. *Mental State:* Ss were required (according to the matron's judgment) to be mentally alert, i.e. show no evidence of senile dementia, and not to have any speech or language disorders (e.g. dysarthria or aphasia) which could interfere with the testing.

At each institution the pre-selected Ss were addressed as a group by the researcher, and the aim of the study was briefly outlined. Ss were told that they would be transported to the University clinic where they would be tested, and that the testing would take approximately one-and-a-half to two hours. Volunteers were requested.

In this way, 39 Ss were obtained, 35 females and 4 males. Although sex was not a criterion, it was hoped that a reasonable proportion of males would be obtained (it was anticipated that the greater majority of Ss would be female, as a report by Hull (1981) indicated that in the USA there were roughly 145 women to every 100 men in 1976). However, there were very few male residents at the institutions, and only a small percentage of these conformed to all the criteria and were willing to act as Ss.

The age range was 60 through to 87 years, with a mean age of 74.2. Although it would have been preferable to have a larger sample of Ss, this would have necessitated involving institutions which were

not in the Cape Town area, which was not practically viable in view of the travelling time to and from the clinic. (Other institutions within the Cape Town area which were not used were either unwilling to participate in the study, or felt that their residents were unsuitable).

No Ss were excluded from the study on the basis of previous history of hearing problems or noise exposure, because the aim was to examine auditory function in the aged population as it presents itself, as was suggested by Møller (1983) and Bergman (1985). Furthermore, it has been suggested that it is unrealistic to expect accurate recall of any confounding factors over a 60 year life span or longer (Hayes, 1984; Osterhammel and Osterhammel, 1979a).

## MATERIALS

### CID W-1 and W-2 Spondaic Word Lists.

Speech reception thresholds were established using the Central Institute for the Deaf (CID) W-1 and W-2 lists. The lists were presented by means of monitored live voice. Maurer and Rupp (1979) and Olsen and Matkin (1978) recommend familiarisation with spondee words prior to testing, both to improve the reliability of the test and to remove any spondees that are unfamiliar to the individual. This would not be possible if recorded materials were used.

CID W-22 Monosyllablic Word Lists.

Monosyllabic discrimination in quiet was assessed with the CID W-22 word lists. These lists were used because they are currently used in most audiology clinics.

The existing recordings of the CID W-22 word lists (lists 1 to 4) currently in use at Tygerberg Hospital were used in this study. The lists were prepared at the acoustic laboratories at the hospital, and were recorded by an English-speaking South African male who has had experience in reading similar speech materials. Each test word is preceded by the carrier phrase, "say the word ...", with a response time of four seconds between each item. The recorded test is preceded by a 1000 Hz calibration signal.

The SPIN Test.

The SPIN test was administered in order to assess discrimination in noise. This test was considered to be most suitable for this purpose since in addition to evaluating the effects of noise in discrimination, it also examines the extent to which context contributes to discrimination.

The materials were prepared according to Kalikow et al's (1977) directions. The eight lists of the SPIN test (see Appendix B) were recorded by the same English-speaking South African male described above. The test sentences were read in an anechoic chamber with a condenser microphone positioned twelve inches from his lips.

As suggested by Kalikow et al (1977), an identifying number precedes each sentence, beginning two seconds before the sentence onset, and

the recorded sentences are spaced ten seconds apart from onset to onset.

The babble was generated by recording each of six adults (three male and three female) reading the same passage from a children's story book in an anechoic chamber with the condenser microphone situated twelve inches from the lips. The six recordings were mixed, each at the same rms level, and two repetitions of the six-voice babble were combined to produce the final 12-voice babble.

The sentences and babble were recorded on separate channels of audio tape (each being preceded by a 1000 Hz calibration signal), so that the intensity of each could be manipulated independently, thus allowing variation of the signal-to-noise ratio. The overall rms level of the babble is constant during the test items, recorded at the same level as that of the test sentences and the number cues. Just before the number cue for each sentence, the overall level of the babble is smoothly decreased by 10 dB. This reduced level is held for the duration of the cue, and then the babble is smoothly restored to the original level prior to the onset of the sentence. According to Kalikow et al (1977), this reduction in the babble level would facilitate a listener's keeping his place in the list, even under less favourable signal-to-noise ratios. All recordings were prepared by professional sound engineers.

Using this recording, Dickens and Delaney (1986) found that the mean scores (and standard deviations) for 80 normal hearing young listeners (thresholds <15 dB re: Ansi 1979 for the octave frequencies from 250 to 8 000 Hz), aged between 18 and 29 years, at 40 dB SL with a S/N of +5 dB were: total = 86,48 (6,42), HP = 98,10 (3,49) and LP = 72,20 (11,04).

Ss were tested using lists 1 and 3, while items from list 7 were used for practice.

Time-compressed Speech (CSPIN).

In order to compare the effects of time-alteration (i.e. time-compression) as opposed to those of noise on discrimination, it is necessary to use similar material. Since the SPIN test was being used to assess speech discrimination in noise, it was decided to use those non-complementary lists of the SPIN to assess the effects of time-compression. This would allow comparison of the effects of noise and time-compression and, in addition, would also allow evaluation of the extent to which context contributes to discrimination of speech which has been down-graded by time-alteration. This material also has the advantage of combining monosyllabic and sentential stimuli.

Sentence lists 6, 7 and 8, recorded at a normal rate (as described above), and without the background babble, were processed through the Lexicon Varispeech Model II at three speed factor dial settings: 1.5, 2 and 2,5. A setting of one corresponds to a normal rate; 1.5 to a rate one and a half times faster than normal or 50% compression; two to a rate twice as fast and, therefore, 100% compression, etc.

Preliminary investigation showed that the performance of 10 normal hearing young listeners (thresholds <15 dB re: ANSI 1979 for the octave frequencies from 250 to 8000 Hz), aged between 18 and 25 years, broke down for the lists compressed at the 2.5 speed factor rate. Thus it was decided to use material compressed at the 2 speed factor rate (i.e. 100% compression). Consequently, lists 6, 7 and 8 were compressed at this rate.

Normative data was then collected from 30 normal hearing young listeners (thresholds <15 dB re: ANSI 1979 for the octave frequencies from 250 to 8000 Hz), aged between 18 and 25 years. The mean scores (and standard deviations) obtained were: total = 90.00 (3.58), HP = 97.09 (3.14) and LP = 82.91 (6.95).

Hearing Handicap Inventory for the Elderly (HHIE).

The shortened version of the HHIE (Ventry and Weinstein, 1982) was used to measure hearing handicap in the elderly. It was considered to be the most suitable scale since it was specifically developed by Ventry and Weinstein (1982) for use with the elderly. The shorter form is reported by the authors to be of comparable reliability to the long form, but it is much faster to administer. A response form (see Appendix A) was prepared for each subject, so that each S's responses were individually recorded by the examiner.

TEST ENVIRONMENT AND INSTRUMENTATION

All testing was conducted in a dual chamber sound treated test suite.

All pure tone and speech testing was conducted on a two-channel Madsen Micro-5 digital audiometer with TDH-39 earphones mounted in *MX/AR supra-aural air cushions. The pure* tone, speech and tape circuits of the audiometer were calibrated according to ANSI 1979 standards.

Recorded speech materials were played on a two-channel (Pioneer Stereo Casette Tape Deck - CT-F650) tape recorder. The speech signal was routed to the audiometer, where the intensity of the signal was determined before it was delivered to the subject via either earphone. For the SPIN test, the signal and babble outputs from the tape recorder were routed to separate channels of the *audiometer so that the intensity* level of each could be separately determined before being delivered to the same earphone. Prior to each test session, the VU meters of each channel of the audiometer were adjusted according to the 1000 Hz calibration signal which preceded each recorded test.

Immittance measures were obtained using a Madsen electro-acoustic impedance bridge (Model ZO73), which delivered a 220 Hz probe tone. This was calibrated according to standards set out in IEC publication 318. Before each test session, the calibration of the *impedance* bridge was checked by means of the built-in 2 cc coupler.

## PROCEDURE

### HHIE

This was administered before audiometric testing so that Ss' responses would not be influenced by performance on the audiometric tests. The Ss were interviewed by the researcher, who completed

the HHIE response form. Administration took approximately 5 minutes.

Pure Tone Audiometry.

Air and bone thresholds were established for each ear, using the "up-5, down-10" procedure described by Green (1978). Thresholds were obtained for the octave frequencies 250, 500, 1000, 2000, 4000 and 8000 Hz. The better or "telephone" ear was tested first, and masking (narrow band noise) of the non-test ear was applied whenever necessary, this being judged according to Goldstein and Newman's (1985) and Studebaker's (1973; 1979) guidelines.

Speech Reception Thresholds.

These were obtained for each ear under earphones. The better ear was tested first, and masking (speech noise) was used when necessary, judged according to Goldstein and Newman's (1985) guidelines. Ss were familiarised with the test words prior to testing, and any problematic words were omitted during the test. Thresholds were determined by monitored live voice presentation according to the procedure described by Chaiklin and Ventry (1964).

CID W-22 Monosyllabic Word Discrimination

Each ear was tested separately and the non-test ear was masked (by means of speech noise) when necessary, judged according to the guidelines set out by Goldstein and Newman (1985). The better ear

was tested first. Discrimination scores were obtained at three presentation levels for each ear: 20, 40 and 60 dB SL re: SRT, unless the 60 dB level exceeded the threshold of discomfort, in which case testing was either conducted at a slightly lower SL, or only 2 discrimination scores were obtained.

*The SPIN Test.*

Each ear was tested separately and the better ear was tested first. Lists 1 and 3 (one to each ear) were presented at a signal-to-noise (S/N) ratio of +5 dB, and at 40 db SL re SRT, as was recommended by Dickens and Delaney (1986). Before administering the test lists, practice items from list 7 at a S/N of +10 dB were presented. Once the Ss had correctly identified 5 out of 8 items correctly, testing commenced. Ss were required to repeat the last word of every sentence.

Time-compressed Speech - the CSPIN Test.

Ss were familiarised with the test procedure using items from list 7 (list 7 time-compressed and without background babble, as described in the materials section), and once correct responses to 5 out of 8 items were received, testing commenced. Each ear was tested separately, and the better ear was tested first. One list was presented to each ear. CSPIN sentence lists (lists 6 and 8) were presented at 40 dB SL re: SRT to enable comparison with SPIN scores. Ss were required to repeat the last word of each sentence.

Acoustic Immittance Measures.

Static compliance measures were obtained for both ears by the conventional method of *subtraction, viz. the compliance* at +200 mm $H_2O$ minus compliance at middle ear pressure (McCandless, 1979), and tympanograms were manually plotted for the range +200 to -200. These were classified according to the system described by Jerger (1970) and Liden et al (1974), cited by Margolis and Shanks (1985). Stapedial reflex thresholds were determined by contra- and ipsi- lateral stimulation in the ascending mode of presentation. *Threshold was defined as the lowest level where the reflex could be* observed in response to two successive stimuli. Thresholds were examined in response to tonal (250, 500, 1000, 2000, and 4000 Hz) and broad band signals in the contralateral mode and to tonal signals only (500, 1000, and 2000 Hz) in the ipsilateral mode.

ANALYSIS OF RESULTS

Data were analysed both quantitatively and qualitatively.

Mean scores, standard deviations and range were determined for the data in order to describe the central tendencies and variability (Shearer, 1982; Ventry and Schiavetti, 1980). Histograms were plotted to illustrate the group trends for the data.

Pure Tone Averages and Acoustic Reflex Thresholds.

PTA scores (average pure tone threshold values at 500, 1000 and 2000 Hz) and BBN ARTs (acoustic reflex thresholds) were examined for differences, according to grouping by decade by means of t-test computations.

Suprathreshold Speech Scores.

In order to examine the influence of age and audiometric configuration on performance for the suprathreshold speech tasks (CID W-22 maximum discrimination, SPIN total, HP, and LP, and CSPIN total, HP, and LP percentage scores) the Ss were sub-divided in two ways:

Grouping by age in decade;

Group I - 60 to 69 years

Group II - 70 to 79 years

Group III - 80 years and older.

Grouping by audiometric configuration;

The system described by Dubno and Dirks (1982) was used.

Group A - flat; < or = 20 dB difference in threshold from 250 to 4000 Hz.

Group B - gradually sloping; 25 to 40 dB difference in threshold from 250 to 4000 Hz, and <30 dB difference in threshold between adjacent octave frequencies.

Group C - steeply sloping; >40 dB difference in threshold from 250 to 4000 Hz, or >30 dB difference between adjacent octave frequencies.

Data were subjected to two factor analyses of variance (ANOVA) with repeated measures on one factor (treatments-by-Groups design) to

examine the difference in speech scores for grouping by age, as opposed to audiogram configuration.

Multivariate analyses and Scheffé post hoc analysis computations were made to determine the specific comparisons which accounted for the significant F-ratios within the interactions (J. Juritz, 1986). Data were analysed according to ears, rather than Ss. Previous research (e.g. Møller, 1983; Osterhammel and Osterhammel, 1979b, Plomp and Mimpen, 1979a, etc.) indicated little statistical difference between ears. For analysis by age decade, any S's two ears would by necessity be included in the same age grouping and, consequently, the use of two ears rather than one would not confound the analysis. However, this was not necessarily the case for the grouping by audiometric shape and, consequently, when the results of the ANOVA showed a significant difference for ears by configuration, further analysis was by S rather than by ear.

HHIE.

Better ear PTA scores were classified into hearing loss categories, as described by Ventry and Weinstein (1983), and the proportion of Ss within each category was compared with the proportion falling within each handicap category. Pass/fail criteria were imposed on pure tone results obtained for each S, and Numbers of Ss falling within these two categories were compared with the degree of handicap as assessed by the HHIE.

The Pearson Product Moment correlation statistic examined the relationship between the HHIE score and audiometric scores (PTA, SRT, and the suprathreshold discrimination scores).

## CHAPTER 4

### RESULTS AND DISCUSSION OF RESULTS

The characteristics of the Ss grouped according to age in decade and audiogram configuration are summarised in Tables 1 and 2.

TABLE 1: MEAN AGE & PTA VALUES FOR Ss GROUPED ACCORDING TO AGE

| GROUP | | PTA | AGE |
|---|---|---|---|
| GROUP I | $\bar{X}$ | 25.77 | 64.91 |
| | SD | 15.33 | 3.93 |
| GROUP II | $\bar{X}$ | 33.44 | 74.72 |
| | SD | 11.81 | 3.04 |
| GROUP III | $\bar{X}$ | 39.90 | 83.30 |
| | SD | 17.66 | 2.20 |

TABLE 2: MEAN AGE & PTA VALUES FOR Ss GROUPED ACCORDING TO AUDIOGRAM CONFIGURATION

| GROUP | | AGE | PTA |
|---|---|---|---|
| GROUP A | $\bar{X}$ | 74.40 | 33.19 |
| | SD | 8.10 | 13.26 |
| GROUP B | $\bar{X}$ | 73.70 | 30.94 |
| | SD | 6.65 | 13.86 |
| GROUP C | $\bar{X}$ | 74.75 | 32.00 |
| | SD | 7.98 | 13.61 |

An interesting feature is that Groups A, B and C do not differ markedly with respect to either mean age or mean PTA values. With the exception of the suprathreshold speech scores, only the possible differences between groups differentiated on the basis of age were examined. Results of the pure tone procedures were examined first, followed by the results of the speech reception and

suprathreshold speech procedures. This was followed by a discussion of the impedance measures. Finally, the results of the HHIE and the relationship between these and other audiometric results were examined.

## PURE TONE THRESHOLDS

Pure tone audiograms were obtained for all 78 ears. When a response could not be obtained at maximum output of the audiometer, the threshold value was recorded as the maximum value plus 5 dB. The majority of the ears (69) presented with sensorineural hearing loss, 7 had a mixed configuration, while 2 (both in the 60-69 year age group) had a conductive loss. The pure tone (air conduction) hearing losses for each group of Ss, and for all the Ss, are shown in Figure 1. The mean values and standard deviations for each octave frequency threshold and PTA scores are presented in Table 3.

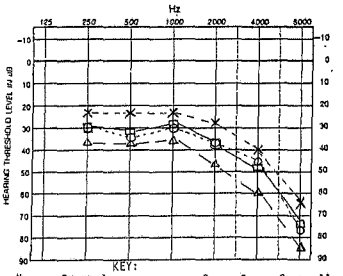



FIGURE 1: MEAN PURE TONE THRESHOLDS FOR ALL Ss, AND AS A FUNCTION OF AGE

TABLE 3: MEANS AND STANDARD DEVIATIONS OF PURE TONE THRESHOLDS, PTA SCORES AND SRT VALUES

| GROUP | | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz | 8000 Hz | PTA | SRT |
|---|---|---|---|---|---|---|---|---|---|
| GROUP I | $\bar{X}$ | 23.84 | 24.55 | 24.32 | 29.32 | 39.77 | 64.55 | 25.77 | 23.40 |
| | SD | 14.05 | 14.05 | 17.95 | 17.61 | 17.21 | 22.57 | 15.33 | 14.59 |
| GROUP II | $\bar{X}$ | 30.14 | 34.17 | 29.58 | 37.08 | 45.46 | 78.47 | 33.44 | 30.97 |
| | SD | 13.87 | 14.17 | 13.11 | 12.84 | 15.76 | 16.81 | 11.81 | 9.09 |
| GROUP III | $\bar{X}$ | 35.50 | 37.50 | 35.25 | 47.00 | 59.75 | 85.75 | 39.90 | 37.75 |
| | SD | 20.49 | 20.49 | 20.55 | 15.34 | 16.10 | 12.06 | 17.66 | 16.42 |
| ALL SUBJECTS | $\bar{X}$ | 29.74 | 32.31 | 29.55 | 37.44 | 47.57 | 76.41 | 32.94 | 30.58 |
| | SD | 15.64 | 16.57 | 16.93 | 16.13 | 17.76 | 19.19 | 15.22 | 13.79 |

It is evident from these results that sensitivity declines with an increase in frequency, for each individual group and for the group as a whole. This is in accordance with previous descriptions of the characteristic age-related loss being a gradually sloping sensorineural loss. The fact that the standard deviation values generally show the same trend, i.e. increase in size with an increase in frequency, indicate that there is more variability in the high frequencies than in the low frequencies. Mean threshold values for frequencies below 4 kHz fall within the normal/mild loss range (Goodman, 1965, cited by Green, 1978), while there is a sharp increase above this, particularly for 8 kHz.

The complete absence of the high frequency air-bone gap reported by Glorig and Davis (1961), amongst others, lends support to Randolph and Show's (1983) contention that the reported conductive component might be an artefact of testing and probably caused by collapsed canals.

Inspection of the data in Table 3 reveals an age effect. The hearing thresholds for each frequency are greatest for Group III, with Group II's values exceeding those of Group I. The results of a 5 year longitudinal study conducted by Møller (1983) showed that sensitivity did continue to decline, especially at the higher frequencies. An interesting aspect of her results was that women showed more of a deterioration than men, and that the decline in sensitivity involved all frequencies, not only the high frequencies as was the case for the males. Although the present results were obtained from a cross-sectional study, they do provide indirect

evidence of a continuing decline in hearing sensitivity with increasing age. The fact that this decline in sensitivity is evident at all frequencies may be due to the fact that the group comprised females almost entirely. The differential effect of sex could not be investigated due to the small number of males in the sample. The lack of males in the study could tempt one to conclude that this sensitivity decline is a true reflection of the aging process, since females are less likely to have been exposed to industrial noise. However, it is not only industrial noise that can lead to hearing loss. Daily exposure to noise encountered in the general environment has also been said to cause hearing loss, i.e. sociocusis (Glorig, 1958). Thus, the question of the relative contribution of noise to the age-related hearing loss remains unresolved, and is likely to remain so, considering that the physiological effects on the cochlea resulting from both noise and aging are similar, so additivity means little in terms of the hearing loss (Corso, 1976, cited by Willeford, 1978).

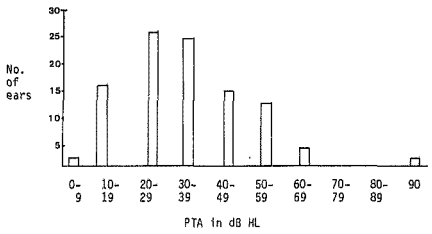



FIGURE 2: DISTRIBUTION OF PTA SCORES

The distribution of PTA scores for the entire sample can be seen in Figure 2. It is evident that the distribution is slightly skewed, which is to be expected for threshold values. As would be predicted from the previous data in Table 3 and Figure 1, the greater proportion of ears show normal/mild degree of hearing loss (20-29 and 30-39 dB categories), with a slightly larger percentage falling into the 10-19 dB category than either the 40-49 or 50-59 dB categories.

The ISO (1982) threshold values which are expected to be exceeded by only 10% of otologically normal 70 year old females generally correspond with the mean threshold values obtained by Group I. However, this group's thresholds exceed the ISO median thresholds for the 60 and 70 year olds, indicating a greater degree of loss. The mean threshold values for the Ss in Group I are also poorer than those reported by Corso (1963). A possible reason for this could be related to the fact that the Ss in the present study were not selected according to the stringent criteria used for the purposes of the ISO (1982) data, or by Corso , i.e. Ss were not excluded on the basis of exposure to noise or other negative case history factors. This was the reason Møller (1983) used to explain the threshold differences between her Ss and the values reported in the literature. The values for the present sample also appear to be larger than those for Møller's unselected sample. In the present study, Ss were all residents of old age homes, while Møller's Ss were drawn from the population at large. It is reasonable to hypothesize that individuals who reside in institutions for the elderly may experience greater physiologic decline,

which may also manifest in reduced threshold sensitivity. Alpiner (1982) reports the incidence of hearing impairment amongst residents of old age homes to be higher than that for the elderly residing in their own homes. Maurer and Rupp (1979) have suggested that stresses associated with social isolation or institutionalisation, for example, appear to be associated with a higher incidence of illness, dependence and suicide. Small sample size may also be a contributing factor, therefore, the possible difference in terms of hearing sensitivity between institutionalised and non-institutionalised individuals needs to be examined in a larger sample.

Administration of the pure tone tests was generally problematic. Ss tended to respond more slowly and less consistently than younger listeners, and needed frequent reassurance, which may be evidence of the anxiety that the elderly are reported to experience in the test situation (Bergman, 1983), especially since this was the first test of the experimental battery. The slowed reaction time could be a reflection of an increased cautiousness of response, which was described by Corso (1977). In addition, cautiousness could also have caused the Ss' hearing ability to be underestimated, which may also partially account for the poorer thresholds found in this study. Increased distractability and slower reaction time amongst the elderly has also been reported by Maurer and Rupp (1979). For most of the Ss in this study, this was only a feature of pure tone testing, and reaction time for the speech tasks was not noticeably slower.

SPEECH RECEPTION THRESHOLDS

Table 3 indicates that there is a good agreement between the speech reception thresholds (SRTs) and the PTA scores. This result was expected, since (to the writer's knowledge) there are no reports in the literature of a poor relationship between the SRT and PTA. For some of the Ss the SRT was established with a reduced number of stimuli due to problems with familiarity. However, this was not thought to adversely affect the results since Punch and Howard (1985) showed that the SRT could be reliably measured using less than the original number of words.

SUPRATHRESHOLD SPEECH MEASURES

The Differential Effects of Age and Audiogram Configuration on Speech Scores.

The means and standard deviations obtained for the speech measures can be seen in Table 4. The results of the ANOVAS to examine the difference between the speech scores for the Ss grouped according to age and audiogram configuration are summarised in Tables 5 and 6. These show that when Ss were grouped according to age there was a significant variance for both main effects, i.e. age and speech-score, while for Ss grouped according to audiogram configuration there was a significant difference for speechscore, but not for audiogram configuration. From these results, it can be concluded that Ss scored differently on the different speech tasks, and that age rather than audiogram configuration is the critical factor which differentiates between Ss.

TABLE 4: MEANS AND STANDARD DEVIATIONS OF SCORES OBTAINED ON THE SPEECH MEASURES

| GROUP | | CIDW.22 MAX | SPIN HP | SPIN LP | SPIN TOTAL | CSPIN HP | CSPIN LP | CSPIN TOTAL |
|---|---|---|---|---|---|---|---|---|
| GROUP I (60-69) | $\bar{X}$ | 91.46 | 58.38 | 45.90 | 67.14 | 86,29 | 69,71 | 78,00 |
| | SD | 13.14 | 8.76 | 12.50 | 8.75 | 20,30 | 23,41 | 20,00 |
| GROUP II (70-79) | X | 88.89 | 79.54 | 37.83 | 58.69 | 80.12 | 58.91 | 70.06 |
| | SD | 9.47 | 14.32 | 20.20 | 14.91 | 14.91 | 17.67 | 12.61 |
| GROUP I (80+) | X | 72.84 | 62.35 | 18.82 | 40.59 | 60.00 | 37.18 | 48.59 |
| | SD | 19.67 | 25.65 | 13.91 | 18.79 | 27.13 | 24.36 | 24.35 |
| ALL SUBJECTS | X | 85.66 | 78.08 | 35.73 | 56.90 | 77.13 | 56.90 | 67.27 |
| | SD | 15.37 | 18.83 | 19.46 | 17.31 | 22.10 | 24.10 | 21.10 |

TABLE 5: ANOVA SUMMARY TABLE SHOWING INTERACTION BETWEEN AGE (A) AND SPEECHSCORE (S)

| | SOURCE | df | F | P |
|---|---|---|---|---|
| CID W-22 x SPIN H x CSPIN H | A | 2 | 12.30 | .0000 |
| | S | 2 | 26.28 | .0000 |
| | SXA | 4 | 1.81 | .1299 |
| CID W-22 x SPIN L x CSPIN L | A | 2 | 14.84 | .0000 |
| | S | 2 | 359.38 | .0000 |
| | SXA | 4 | 2.43 | .0509 |
| CID W-22 x SPIN T x CSPIN T | A | 2 | 15.65 | .0000 |
| | S | 2 | 235.15 | .0000 |
| | SXA | 4 | 3.19 | .0154 |

TABLE 6: ANOVA SUMMARY TABLE SHOWING INTERACTION BETWEEN AUDIOGRAM CONFIGURATION (G) AND SPEECHSCORE (R)

| | SOURCE | df | F | P |
|---|---|---|---|---|
| CID W-22 x | G | 2 | 1.48 | .2346 |
| SPIN H x | R | 2 | 22.76 | .0000 |
| CSPIN H | RXG | 4 | 1.98 | .1004 |
| CID W-22 x | G | 2 | 1.95 | .1502 |
| SPIN L x | R | 2 | 253.86 | .0000 |
| CSPIN L | RXG | 4 | 1.46 | .2188 |
| CID W-22 x | G | 2 | 1.82 | .1703 |
| SPIN T x | R | 2 | 170.26 | .0000 |
| CSPIN T | RXG | 4 | 2.29 | .0632 |

The lack of differentiation between the audiometric groups could possibly be explained by the fact that, for some of the speech tasks, sentence stimuli were used, i.e. the *SPIN* and *CSPIN HP* items, and Dubno and Dirks (1982) report that the relationship between discrimination and audiometric configuration is weakened when sentences are used as stimuli. However, this does not explain the lack of variance between the Ss for the other speech measures, viz. the CID W-22 maximum and the LP items of the SPIN and CSPIN tests. A more likely explanation may be that the difference between the groups are qualitative rather than quantitative. Another confounding variable may be related to sample size. Only 8 ears comprised the third audiogram configuration category. A larger number of Ss, with fairly equal numbers within each group, would allow for a more realistic examination of the differential effect of audiometric configuration on discrimination scores. Because age rather than audiometric configuration was the significant variable, analysis of results in terms of ears rather than Ss could continue, since any S would, by necessity, contribute data from both ears to the same decade group, which would not necessarily be the case for grouping by audiometric configuration.

*The Age Effect.*

The variance in age was further investigated by means of multivariate analysis and Scheffe post hoc comparisons. The Scheffe test results are summarised in Table 7. These indicate that the scores obtained by Group III differed significantly from those obtained by the other two groups. This difference was apparent for

TABLE 7: SUMMARY OF SCHEFFÉ VALUES SHOWING SIGNIFICANT AGE GROUP VARIATIONS FOR SPECIFIC SPEECH TASKS

| | SPEECHSCORE | $A_1$ - $A_2$ | $A_1$ - $A_3$ | $A_2$ - $A_3$ |
|---|---|---|---|---|
| $A_1$ = 60-69 | Max. CID W22 | 1.2 | *** 4.215 | ** 3.487 |
| $A_2$ = 70-79 | SPIN H | 1.6741 | *** 4.8738 | ** 3.7609 |
| $A_3$ = 80+ | CSPIN H | 1.1064 | *** 4.0337 | ** 3.3736 |
| | SPIN L | 1.7360 | *** 4.8347 | ** 3.6602 |
| | CSPIN L | 1.8283 | *** 4.7118 | ** 3.4397 |
| | SPIN T | 1.952 | *** 5.675 | *** 4.448 |
| | CSPIN T | 1.5613 | *** 4.948 | *** 3.9365 |

F CRIT 2,68 : 2.501 : $p < 0.05$ *

3.138 : $p < 0.01$ **

3.908 : $p < 0.001$ ***

all the speech measures. While the mean values for the speech tasks seen in Table 3 show a tendency for performance to deteriorate with increasing age for all the tests, the difference between Groups I and II was not found to be statistically significant.

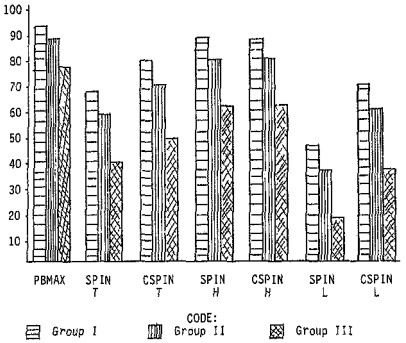



FIGURE 3: DISTRIBUTION OF SCORES FOR THE THREE AGE GROUPS FOR THE SUPRATHRESHOLD SPEECH TASKS

The tendency for scores to decrease as a function of age is graphically illustrated in Figure 3. This performance difference could reflect a loss effect, since mean PTA scores also reflect an increase with corresponding increase in age. However, t-test computations (summarised in Table 8) show that the PTA values for Group I differ significantly from Groups II and III, with no significant difference between the latter two groups. This is in

*contrast to the speech* score differences, where Groups I and II were not statistically differentiated. The data therefore suggests a complex interaction between age *and degree of loss, and supports* Bess and Townsend's (1977) finding that discrimination ability is dependent on both age and degree of loss. The latter study, however, did not find any age effect for Ss with PTA scores below 49 dB. The mean PTA values for the three groups in the present study are all below 49 dB, and a general trend for an age-related reduction in discrimination was evident. The fact that Bess and *Townsend (1977) did not see much* of an age effect for Ss with smaller PTA scores could be due to their age grouping, i.e. by twenty year spans rather than by decade. *The present results* indicate that a significant age X degree of loss interaction occurs when the loss exceeds 33 dB (mean PTA value for Group II), and that the trend for scores to deteriorate with increasing age is also apparent for smaller PTA values.

TABLE 8: SUMMARY OF t-TEST VALUES SHOWING SIGNIFICANT *PTA DIFFERENCE*

| COMPARISON | t-VALUE |
|---|---|
| Groups I X II | 2.085 * |
| Groups II X III | 1.822 |
| Groups I X III | 2.776 ** |

* $p < 0.05$ ** $p < 0.01$

CID W-22 Discrimination Scores.

The distribution of the CID W-22 maximum scores for each group and the entire sample can be seen in Figure 4. This shows that the majority of Ss (56%) had discrimination scores which were better than 91%, which can be seen to refute the statement that disproportionately poor speech discrimination scores are a general feature of age-related hearing loss. This supports Møller's (1981, cited by Møller, 1983) finding, although the present proportion is slightly lower than Møller's. The reason for this may be twofold;

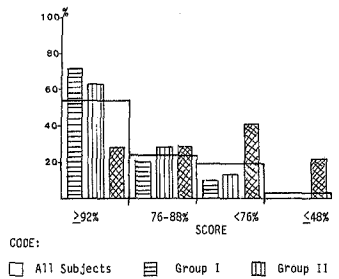



FIGURE 4: CID W-22 MAXIMUM DISCRIMINATION SCORES

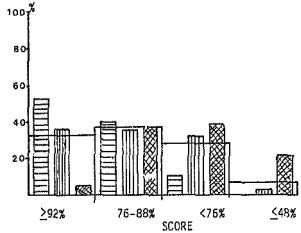
Møller only used 70 year old Ss (reassessed at 75), and their average loss was less severe. The difference in scores between

Group III and the other groups is in agreement with an earlier study by Jerger (1973). He found that discrimination decreased as a function of age, but the reduction in scores was gradual until about 80 years, after which age there was a significant drop.

In addition to the quantitative difference between Groups III, and I and II, Figure 4 also illustrates the qualitative differences (in terms of general distribution). Groups I and II follow a similar trend (which is the trend shown by the entire sample), i.e. the majority of Ss show good discrimination, with only 9% and 14%, respectively, obtaining scores below 76%. The pattern for Group III differs, showing a flatter distribution curve with the majority (37%) having scores below 76%. This further illustrates the complex interactive effects of age and degree of loss on discrimination.

The SPIN Test.

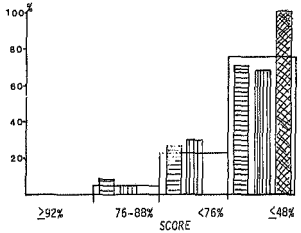
Examination of the SPIN scores show that there is the expected HP and LP separation, and that the scores are reduced in relation to those for normal hearing young Ss. Dickens and Delaney (1986) report scores of 98% and 72% for the HP and LP conditions, respectively, obtained at 40 dB with a S/N ratio of +5 dB. Table 4 shows that while both HP and LP scores are reduced, the reduction is much larger for the LP items, and that this becomes more pronounced with increasing age.




CODE:

☐ All Subjects ▤ Group I ▥ Group II ▩ Group III

FIGURE 5: SPIN HP DISCRIMINATION SCORES




CODE:

☐ All Subjects ▤ Group I ▥ Group II ▩ Group III

FIGURE 6: SPIN LP DISCRIMINATION SCORES

Figures 5 and 6 show the distribution of scores for the entire sample and for the different age groups for the *SPIN HP and LP*

items. While the SPIN HP scores show no real trend (distribution curves for the three groups are different), a clear trend is seen for the SPIN LP scores. This is seen for all three groups, with the only difference relating to quantity. The majority of the Ss performed poorly on the LP items (scores <49%), while there was a fairly broad, not very well defined, distribution for the HP items. The distribution of scores for the test as a whole (SPIN TOTAL, seen in Figure 7), once again show the qualitative differences. The distribution for Groups I and II is similar, but not Group III.

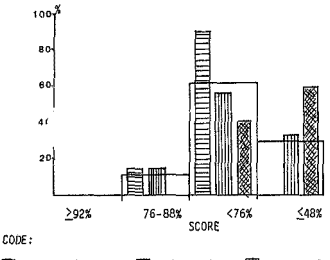



FIGURE 7: SPIN TOTAL DISCRIMINATION SCORES

The CSPIN Test.

CSPIN scores show a similar trend to the SPIN scores, i.e. there is a separation between the HP and LP scores, and the scores are lower

than those obtained by normal young listeners (HP = 97%, LP = 83% for the 30 normal hearing young listeners referred to in the methodology section). Reduced performance, in comparison with young listeners, is in agreement with other studies e.g. Schmitt and McCroskey (1981); Schon (1977), etc. Once again, the effects of the distortion (in this case compression) are seen to be more disruptive for the LP stimuli than for the HP stimuli.

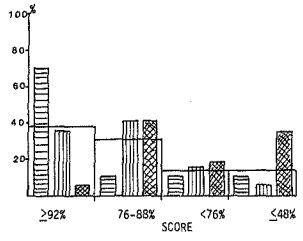



FIGURE 8 : CSPIN HP DISCRIMINATION SCORES

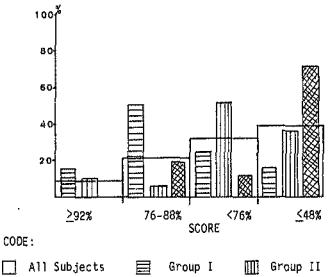



FIGURE 9: CSPIN LP DISCRIMINATION SCORES

The distribution of the scores can be seen in Figures 8 and 9. No general trend for either the HP or the LP items can be seen for any of the groups. An interesting finding is that the distribution for Group III seems to be bimodal fo. both HP and LP, i.e. there appear to be two peaks. The distribution of the HP scores shifts from 6% to 41%, then down to 18% and up to 35%, while that for LP shifts down from 19% to 11% and up again to 71%. The low scores may reflect central involvement and the distribution could indicate that two groups of Ss are involved, viz. some with relatively well preserved central auditory function, and those with central auditory problems, as was suggested by Møller (1983). This may also be supported by the fact that the standard deviations for Group III were largest for this measure (although not substantially

larger than those found for Group I for the CSPIN procedure). The possibility of a bimodal distribution needs to be investigated in a larger sample.

No clear distribution pattern is evident for the TOTAL scores (seen in Figure 10) and, here, the bimodal nature of the distribution for Group III has been obscured. Computation of TOTAL scores for either the SPIN or the CSPIN procedures is not recommended. The total score does not provide any additional information and, in some instances, may actually obscure potentially useful information, e.g. SPIN LP and CSPIN.

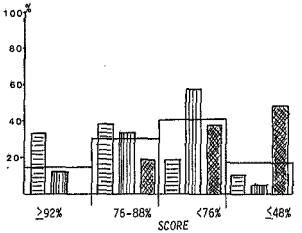



FIGURE 10: CSPIN TOTAL DISCRIMINATION SCORES

TABLE 9: SUMMARY TABLE OF SCHEFFÉ VALUES SHOWING SIGNIFICANT SPEECHSCORE VARIATION WITHIN AGE GROUPS

$S_1$ = CID W-22 max.
$S_2$ = SPIN H
$S_3$ = CSPIN H

| GROUPS | $S_1 - S_2$ | $S_1 - S_3$ | $S_2 - S_3$ |
|---|---|---|---|
| $A_1$ (60-69) | 1.6829 | 2.4219 | .0738 |
| $A_2$ (70-79) | ** 3.701 | *** 3.9755 | .2703 |
| $A_3$ (79+) | *** 4.4917 | *** 5.2393 | .7476 |

$S_1$ = CID W-22 max.
$S_2$ = SPIN L
$S_3$ = CSPIN L

| GROUPS | $S_1 - S_2$ | $S_1 - S_3$ | $S_2 - S_3$ |
|---|---|---|---|
| $A_1$ (60-69) | *** 13.643 | *** 6.7667 | *** 6.8764 |
| $A_2$ (70-79) | *** 18.647 | *** 10.925 | *** 7.7215 |
| $A_3$ (79+) | *** 14.9788 | *** 10.2084 | *** 4.7703 |

$S_1$ = CID W-22 max.
$S_2$ = SPIN T
$S_3$ = CSPIN T

| GROUPS | $S_1 - S_2$ | $S_1 - S_3$ | $S_2 - S_3$ |
|---|---|---|---|
| $A_1$ (60-69) | *** 10.198 | *** 5.938 | *** 4.2596 |
| $A_2$ (70-79) | *** 14.721 | *** 9.3587 | *** 5.364 |
| $A_3$ (79+) | *** 13.368 | *** 9.839 | * 2.823 |

F CRIT 2,68: 2.501 : $p < 0.05$ *
3.138 : $p < 0.01$ **
3.908 : $p < 0.001$ ***

Speechscore Variation.

The results of the Scheffé computations to investigate significant speechscore variation within the different age groups can be seen in Table 9. For Group I there was no significant difference between scores obtained for the CID W-22, the SPIN HP and the CSPIN HP procedures, and for both Groups II and III there was no difference between the SPIN HP and CSPIN HP scores. For all the other measures the speech score variation was found to be significant within all three age groups, indicating that the tests assess different aspects of auditory discrimination.

The lack of significant difference for the HP measures for all Ss, regardless of age or audiometric configuration, is interesting. Introduction of noise and compression did not have a differential effect on HP performance, while for the LP sentences the two conditions were differentiated. Thus, the important feature seems to be context, which apparently helps to overcome the distortion, regardless of the nature of the distortion. This has important implications for rehabilitation with the elderly hearing impaired client, in that more emphasis should be placed on teaching him to utilise contextual information in order to overcome problems which he experiences in the less than ideal type of communicative situation. The fact that Group I did not show any statistically significant difference between discrimination of undistorted stimuli (CID W-22 word lists) and the two degraded conditions, while Groups II and III did, is also important. While the youngest group's performance on the HP items of the SPIN and CSPIN tests could be predicted on the basis of their monosyllabic discrimination, this was not the case for the older Ss.

Examination of Table 4 and Figure 3 shows that, with the exception of the speech tasks discussed above, for all Ss the scores obtained for the CID W-22 lists were the highest, with CSPIN and SPIN following in that order. Very often the elderly specifically complain of problems in understanding speech in noise, yet this aspect is not routinely investigated and, frequently, hearing aids are fitted without evaluating aided performance in the presence of noise. The present results indicate that the Ss perform differently in noise and quiet, supporting previous research by Duquesnoy (1983) and Plomp and Mimpen (1979a), which showed that Ss with the same hearing loss for speech in quiet may differ in their performance in noise, and that this could not really be predicted from the performance in quiet. The fact that the scores for the speech measures in quiet and noise differ significantly suggests that different aspects of auditory function are being measured. A study by Festen and Plomp (1983) provides support for this. They investigated the relationship between various auditory functions in hearing-impaired individuals, and concluded that hearing loss for speech in quiet is determined by audiometric loss, while hearing loss for speech in noise is governed by frequency resolution abilities. If different aspects of auditory function are being measured, as this and previous research suggests, it is necessary to include, in the routine audiologic battery, a test which evaluates discrimination in noise. While future research may reveal diagnostic sensitivity of such a procedure, in that it may differentiate between Ss with certain types of disorder and/or sites of lesion, a more immediate gain or benefit would be in the field of hearing aid fitting. Patients with sensorineural hearing

losses require a higher S/N ratio than normal hearing individuals, and their speech discrimination in noise problems are related to this unaided S/N threshold (Welzl-Müller and Sattler, 1984).

While the SPIN test can give an indication of discrimination ability in noise, and the extent to which contextual cues are being utilised (which provides information necessary for planning rehabilitation), it would not seem to be the most ideal procedure to acquire the specific information (in terms of the aided and unaided S/N ratios) required to improve the selection of hearing aids. Both the presentation level and S/N ratio influence performance, thus the determination of performance functions at various presentation levels and S/N ratios would give the best estimate of an individual's ability to understand speech in noise (Dickens and Delaney, 1986). To do this using the SPIN test would be very time consuming, and not very practical. The Ss in the present study all reported that the SPIN test was very difficult and that they found it tiring, so the administration of more than one list per ear does not seem a viable proposition. A more practical approach would be the adaptive procedure described by Dirks, Morgan and Dubno (1982). In this approach the S/N ratios required to obtain 50% correct discrimination for monosyllabic (NU-6) words presented at several fixed presentation levels are plotted, and compared with the curve obtained from normal hearing young listeners. These authors found that these curves gave as much information as a series of individual performance intensity functions (PIFs) for different S/Ns plotted at different levels, yet were much faster to administer. Their preliminary research has indicated that this adaptive

procedure can differentiate between ears and Ss with similar PIFs in quiet and may, therefore, be a means by which clinicians can predict an individual's relative performance with an aid, and help the clinician choose the most suitable ear for amplification.

The fact that all the Ss performed more poorly on the SPIN than on the CSPIN test would seem to provide little support for central processing problems being a general characteristic of age-related auditory changes, as has been suggested by several authors, e.g. Bergman (1983); Sticht and Gray (1969), etc. However, as previously mentioned, their scores are reduced in comparison with those obtained by normal hearing young listeners. The reduction in performance on both the CSPIN and the SPIN tests could be seen as evidence of central processing problems (i.e. compressed speech is generally considered to be sensitive to disorders in the central auditory nervous system, and all Ss performed more poorly on the SPIN). It could be argued that the noise element in the SPIN test reduces the redundancy of the speech signal to a greater degree than the compression in the CSPIN test and, that it is therefore tapping more subtle CANS disorders. However, the more likely explanation is that reduced performance on the SPIN is the result of peripheral processing problems, as suggested by Plomp and Mimpen (1979) and Festen and Plomp (1983), and that the reduction in performance on the CSPIN may also be due to the peripheral involvement rather than central problems. Further support for this is seen in a study by Era, Jokela, Qvarnberg and Heikinen (1986). They found that elderly Ss had more difficulty with speech in noise than with reduced redundancy speech (interrupted speech), and they

suggested that peripheral auditory functions are important determinants of performance in speech discrimination tests.

The large standard deviations for the CSPIN procedure, and the apparent bimodal distribution for the oldest group, may suggest that in this sample there were individuals with well-preserved central auditory function, as well as those with central processing problems. Before any final comment can be made concerning either the question of central processing problems in the elderly, or the clinical utility of this test, further research needs to be conducted, firstly, to determine the sensitivity of this test in detecting CANS disorders in patients with documented lesions and, secondly, to establish the influence of peripheral sensitivity loss on young listeners' performance on the CSPIN test. Furthermore, besides the relative contribution of peripheral and central disorders, the anxiety factor must not be ignored. Bergman (1983) states that performance can be adversely affected by stress, especially in difficult listening circumstances.

## IMMITTANCE MEASURES

### Tympanometry and Static Compliance Values.

Tympanograms were recorded for 71 ears. Seals could not be obtained on the remaining 7 ears. The distribution of tympanograms can be seen in Table 10.

TABLE 10: DISTRIBUTION OF TYMPANOGRAMS ACCORDING TO JERGER (1970) AND LIDEN ET AL (1974), CITED BY MARGOLIS AND SHANKS (1985)

| | A | As | Ad | B | C | CNT |
|---|---|---|---|---|---|---|
| I (n = 22) | 17 | 2 | 2 | - | - | 1 |
| II (n = 36) | 26 | 3 | 3 | 2 | - | 2 |
| III (n = 20) | 14 | 1 | 1 | - | - | 4 |
| Total (n = 78) | 57 | 6 | 6 | 2 | - | 7 |

With the exception of two type B tympanograms (obtained from the same subject), all others fell within the shape A category, with the majority of these showing compliance values within the normal range. An equal number of tympanograms with higher than normal (type Ad), and with lower than normal (type As), compliance values were found. *There was no incidence of negative middle ear pressure* peak (type C). The low incidence of type B tympanograms is in agreement with what has been reported in the literature (Orchik, 1981). Although little is known about changes in the tympanogram that might be related to the aging process, it has been suggested by Orchik (1981) that there is likely to be a higher incidence of tympanograms associated with ossicular abnormality. However, this does not seem to be the case for the present sample, since the

majority of the tympanograms were normal type A, with a mean static compliance value of ,55 cc. The mean static compliance values for each tympanogram type across the three age groups can be seen in Table 11.

TABLE 11: MEAN STATIC COMPLIANCE VALUES FOR EACH AGE GROUP

| GROUP | | TYMPANOGRAM A | As | Ad |
|---|---|---|---|---|
| GROUP I | $\bar{X}$ | .52 | .2 | 2.0 |
| | SD | .24 | - | - |
| GROUP II | $\bar{X}$ | .61 | .2 | 2.17 |
| | SD | .40 | - | - |
| GROUP III | $\bar{X}$ | .47 | .2 | 2.0 |
| | SD | .19 | - | - |

These values are similar for each group, and do not indicate any change with increasing age, although the values obtained can be considered to be at the lower end of the scale. Research by Hall (1979) and Jerger et al (1972) described a systematic decline in static compliance with increasing age, which was attributed to middle ear changes. This effect was reported to be more pronounced in females, consequently a similar trend would be expected, but is not clearly seen. However, the fact that the compliance values tend towards the lower end of the scale may indicate a trend in

this direction, which supports the work of Osterhammel and Osterhammel (1979b). These researchers found that while static compliance values were unrelated to either age or sex, these measures did show a decline with increasing age that was not statistically significant.

In conclusion, aging does not seem to have any significant effect on tympanogram shape or static compliance measures. This result is hardly surprising, considering the problems associated with obtaining and interpreting these measures. One of the major weaknesses of static compliance is the wide variance in values related to specific pathologies, with these showing considerable overlap amongst normal, flaccid and stiff middle ear systems (Alberti and Kristensen, 1970; Northern and Downs, 1984). With this variability being recorded from systems with clearly defined physical changes, it would be naive to expect a characteristic value from the aged ear, when many different structural changes have been reported to occur in the aging middle ear system (Nadol, 1981; Wofford, 1981). Furthermore, measurements can be affected by the equipment used (Thompson et al, 1979). A limitation of the present study is that the tympanograms and static compliance values were manually recorded and calculated, which decreases the accuracy of measurement and could, consequently, have obscured small variations.

Acoustic Reflex Measures - Pure Tones.

Reflexes were recorded for both crossed/contralateral stimulation (0.25, 0.5, 1, 2 and 4 kHz), and uncrossed/ipsilateral stimulation (0.5, 1 and 2 kHz). In addition to ears with abnormal tympanograms and those with reflexes absent at the limits of the audiometer, reflexes could not be evaluated in 3 ears due to a high degree of movement artefact. Mean reflex thresholds for the group and for each age-group can be seen in Table 12.

Mean threshold values compare favourably with those reported by Osterhammel and Osterhammel (1979b). Little difference between the values for each age group is evident, for both crossed and uncrossed reflexes, and there is similarly little difference between crossed and uncrossed values. However, it was noted that uncrossed reflexes could not be recorded at the limits of the audiometer in a greater number of ears than was the case for crossed reflexes. The possible explanation for this may be related to reflex amplitude. Reflex amplitude per se was not investigated, but Hall (1985; 1982), Wilson (1981) and Thompson et al (1980) have reported that aging profoundly affects reflex amplitude, i.e. it decreases with increasing age. Hall also reported that these age-related changes were more pronounced for uncrossed than crossed reflexes. Thus, reduced amplitude could make measurement more difficult (especially when using the Madsen ZO 73 without a recorder) and, therefore, account for the fewer number of observations.

TABLE 12: MEAN REFLEX THRESHOLDS IN dB HL FOR CROSSED AND IN dB SPL FOR UNCROSSED REFLEXES

| GROUP | | FREQUENCY IN Hz | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | CROSSED | | | | | UNCROSSED | | |
| | | 250 | 500 | 1000 | 2000 | 4000 | 500 | 1000 | 2000 |
| GROUP I | $\bar{X}$ | 89.07 | 87.14 | 87.50 | 93.57 | 86.67 | 90.42 | 88.33 | 88.75 |
| | SD | 8.96 | 9.75 | 11.22 | 10.46 | 13.23 | 8.12 | 9.13 | 9.80 |
| GROUP II | $\bar{X}$ | 90.00 | 88.85 | 84.20 | 88.54 | 94.05 | 88.10 | 86.20 | 85.71 |
| | SD | 12.54 | 14.85 | 11.15 | 8.78 | 12.91 | 8.58 | 10.24 | 9.39 |
| GROUP III | $\bar{X}$ | 87.50 | 89.29 | 90.36 | 98.85 | 103.75 | 81.67 | 83.89 | 88.33 |
| | SD | 13.12 | 13.71 | 15.38 | 15.16 | 16.64 | 8.29 | 8.58 | 8.17 |
| ALL SUBJECTS | $\bar{X}$ | 89.31 | 88.52 | 86.70 | 92.55 | 94.34 | 87.38 | 86.31 | 87.05 |
| | SD | 11.72 | 13.20 | 12.44 | 11.72 | 14.62 | 8.78 | 9.50 | 9.23 |

TABLE 12: MEAN REFLEX THRESHOLDS IN dB HL FOR CROSSED AND IN dB SPL FOR UNCROSSED REFLEXES

| GROUP | | FREQUENCY IN Hz CROSSED | | | | | UNCROSSED | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 250 | 500 | 1000 | 2000 | 4000 | 500 | 1000 | 2000 |
| GROUP I | $\bar{X}$ | 89.07 | 87.14 | 87.50 | 93.57 | 86.67 | 90.42 | 88.33 | 88.75 |
| | SD | 8.96 | 9.75 | 11.22 | 10.46 | 13.23 | 8.12 | 9.13 | 9.80 |
| GROUP II | $\bar{X}$ | 90.00 | 88.85 | 84.20 | 88.54 | 94.05 | 88.10 | 86.20 | 85.71 |
| | SD | 12.54 | 14.85 | 11.15 | 8.78 | 12.91 | 8.58 | 10.24 | 9.39 |
| GROUP III | $\bar{X}$ | 87.50 | 89.29 | 90.36 | 98.85 | 103.75 | 81.67 | 83.89 | 88.33 |
| | SD | 13.12 | 13.71 | 15.38 | 15.16 | 16.64 | 8.29 | 8.58 | 8.17 |
| ALL SUBJECTS | $\bar{X}$ | 89.31 | 88.52 | 86.70 | 92.55 | 94.34 | 87.38 | 86.31 | 87.05 |
| | SD | 11.72 | 13.20 | 12.44 | 11.72 | 14.62 | 8.78 | 9.50 | 9.23 |

For the crossed reflexes, a slight decline in the number of ears in which a reflex could be recorded was seen with an increase in frequency from 0.25 kHz to 2 kHz (100%, 93%, 91% and 88%). This can be explained in the context of the pure tone sensitivity results. The general configuration was a sloping loss, consequently one may predict that more reflexes may be absent in the higher frequencies due to the degree of loss. At 4 kHz the reflex could not be evaluated in 38% of the ears. This large decrease cannot be entirely explained by the audiometric configuration. Jerger et al (1972) and Osterhammel and Osterhammel (1979b) have also reported being unable to elicit a reflex at this frequency in a certain percentage of apparently normal ears. Both these studies, however, report a smaller percentage of absent reflexes than that for the present study (Jerger et al, 3%; Osterhammel and Osterhammel, 6%). In both these studies the age range of Ss used was very large, i.e. the studies were not confined to the elderly population, which could perhaps have obscured a higher tendency for the absence of a 4000 Hz reflex in this population.

*Acoustic Reflex Measure - Broadband Noise (BBN).*

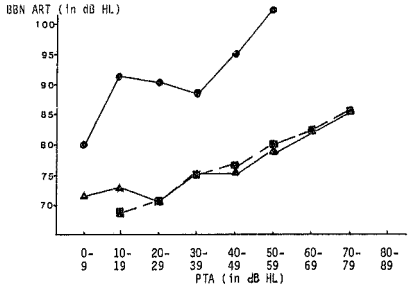
These measures were obtained for crossed stimulation only. The values for the total sample and for each age group can be seen in Table 13.

TABLE 13: MEAN BBN REFLEX THRESHOLDS

| GROUP | $\bar{X}$ | SD |
|---|---|---|
| GROUP I | 87.50 | 8.71 |
| GROUP II | 89.20 | 8.98 |
| GROUP III | 97.14 | 12.20 |
| ALL Ss | 90.85 | 10.41 |

The mean values are not that different from the mean pure tone ART values (see Table 12). This reflects an elevation of the BBN ART, since the BBN reflex is normally elicited at lower levels than the tonal reflexes. These results are similar to those of Wilson (1981). He found that the elderly population demonstrate a smaller noise-tone difference, and that their BBN ARTs were significantly higher than those of young Ss. Silman (1979) also reported that BBN ART is elevated in the elderly population, but he found that it was still elicited at a lower level than the pure tone ARTs. These results indicate that there is a tendency for the BBN reflex to be elicited at higher levels with increasing age, while tonal reflexes are relatively unaffected by age, in contrast to the study by Jerger et al (1978), which reported that tonal ARTs decrease with increasing age and BBN ARTs are unaffected by age.

Jerger et al (1978) also examined the effect of hearing loss on the BBN ART, and showed that the BBN ART shows a systematic increase with increasing hearing loss, regardless of audiometric configuration. Figure 11 shows the present results (mean BBN ART as a function of PTA) in relation to those obtained by Jerger et al.




KEY:

● Present Study

▲ Jerger et al, elderly with flat configurations

■ Jerger et al, elderly with sloping configurations

FIGURE 11: EFFECT OF HEARING LOSS ON THE REFLEX THRESHOLD FOR BBN - A COMPARISON WITH JERGER ET AL (1978)

The Jerger et al (1978) study found that there was an age effect only for losses exceeding 50 dB HL. A similar complex interaction between age and degree of loss was seen in the present study, but for PTA values below 50 dB HL. The t-test values (see Table 14) show that the mean BBN ART obtained by Group III differs significantly from the BBN ARTs obtained by either of the other two groups. No significant difference was seen for Groups I and II. A similar trend was seen for the PTA values (refer to Table 8).

TABLE 14: SUMMARY OF t-TEST VALUES SHOWING SIGNIFICANT BBN ART DIFFERENCE
(* $p < .05$)

| COMPARISON | t-VALUE |
|---|---|
| GROUP I X GROUP II | .5624 |
| GROUP II X GROUP III | 2.2814 * |
| GROUP I X GROUP III | 2.3952 * |

Thus it would seem that the combination of increasing age and increasing hearing loss affect the BBN threshold, while the tonal reflex threshold appears to be relatively unaffected by age.

HHIE

The results of the HHIE showed that 26 (i.e. 67%) of the Ss considered themselves to have no hearing handicap, 9 (23%) felt that they were mildly handicapped, and only 4 (10%) Ss indicated that they had a significant handicap.

TABLE 15: DISTRIBUTION OF Ss BY HEARING LEVEL/HANDICAP CATEGORIES

| HEARING LEVEL | HHIE CATEGORIES 0-8 | 10-22 | 24-40 | TOTAL |
|---|---|---|---|---|
| 0 - 25 dB | 14 | - | 2 | 16 |
| 26 - 40 dB | 9 | 4 | 1 | 14 |
| 41 - 55 dB | 3 | 5 | 1 | 9 |
| TOTAL | 26 | 9 | 4 | 39 |

Table 15 shows the relationship between the three categories of hearing handicap and the PTA score (500, 1k and 2 kHz) for the better ear. The imperfect relationship between pure-tone sensitivity and hearing handicap is clearly seen here. While 88% of the Ss with no hearing impairment (i.e. 14 of the 16 Ss) report no handicap, only 11% of those (i.e. one subject) with hearing loss exceeding 40 dB report significant handicap. Ventry and Weinstein (1983) reported a better relationship - 70% of their Ss with a significant loss (PTA > 55 dB), and 48% of those in the 41-55 dB category reported a significant handicap. The lower relationship between degree of loss and significant handicap may possibly be explained by the fact that in the present study there were no Ss with a significant loss (i.e. PTA > 55 dB). The HHIE may show a better relationship with pure tone sensitivity at the two ends of the scale, viz., no loss as opposed to significant hearing impairment, and show a less perfect relationship for those Ss with milder impairment.

By combining the no-handicap and the mild-handicap categories, Ventry and Weinstein illustrated that the 40 dB cut-off clearly

separated those individuals who experience hearing handicap from those with no handicap. The proportion of their Ss with loss <40 dB reporting no handicap was much greater than those who reported handicap, and the opposite relationship was found for those Ss whose loss exceeded 40 dB. In the present study it was also found that the majority (90%) of Ss with PTA scores of less than 41 dB reported no handicap. However, this was also true for those with a loss greater than 40 dB, in that eight of the nine Ss in this category reported no handicap. Furthermore, of the four Ss who reported significant handicap, only one had a loss which exceeded 40 dB.

There appears to be a good relationship between good hearing sensitivity and absence of handicap, as measured by the HHIE, but the HHIE does not seem to be exploring the possible handicap that individuals with reduced pure tone sensitivity may be experiencing. A possible factor which may have confounded the results is that the HHIE was administered by the researcher as the first test of the experimental battery and pride may have caused some of the Ss to negate, or not accurately evaluate, their hearing difficulties. Different results may possibly have been obtained had the Ss completed the questionnaire themselves, or had it been administered at the end of the battery.

In order to further investigate the use of the 40 dB cut-off in screening, the proportion of Ss who would have passed or failed an audiometric screening test in each HHIE category was examined.

Data was obtained by inspecting each S's audiogram and applying Ventry and Weinstein's (1983) recommended pass/fail criterion (i.e.

a fail on the audiometric screening test would be an inability to hear a 40 dB tone at 1 or 2 kHz in each ear). For the purposes of this investigation a fail was, therefore, equated with a threshold of at least 45 dB in each ear at 1 or 2 kHz, and 28 of the Ss were found to have passed the "screening test", while the other 11 Ss failed it.

Table 16 illustrates the relationship between the handicap and pass/fail categories. The accuracy in terms of a low false positive rate is clearly illustrated. The greater majority of Ss reporting no handicap also passed the screening test. For those Ss reporting some degree of handicap the proportion of those who passed or failed the screening test were roughly equal. The HHIE thus would appear to be more sensitive to true negative conditions (no loss and no handicap) since overall 67% of the sample reported no handicap and 72% passed the screening test. It appears to be less accurate in cases of loss and/or handicap. Thus, the HHIE, unlike other scales, e.g. the HHS or the HMS, does not seem to be sensitivity weighted (although this could be due to small sample size in general and, in particular, to the lack of Ss having significant loss).

TABLE 16: PURE TONE PASS/FAIL DATA AS A FUNCTION OF HEARING HANDICAP CATEGORIES

| HHIE CATEGORIES | PURE TONE SCREEN | | |
|---|---|---|---|
| | FAIL | PASS | TOTAL |
| 0 - 8 | 5 | 21 | 26 |
| 10 - 22 | 5 | 4 | 9 |
| 24 - 40 | 1 | 3 | 4 |
| TOTAL | 11 | 28 | 39 |

TABLE 17: SUMMARY OF THE PEARSON-PRODUCT MOMENT CORRELATIONS BETWEEN THE HHIE AND BETTER EAR AUDIOMETRIC MEASURES FOR ALL THE Ss AND EACH GROUP OF Ss

| GROUP | | PTA | SRT | CIDW-22 | SPIN T | SPIN H | SPIN L | CSPIN T | CSPIN H | CSPIN L |
|---|---|---|---|---|---|---|---|---|---|---|
| GROUP I | HHIE | 0.19 | 0.00 | -0.24 | -0.42 | -0.43 | -0.29 | -0.47 | -0.43 | -0.43 |
| GROUP II | | 0.24 | 0.20 | 0.18 | 0.01 | 0.28 | -0.18 | -0.02 | 0.24 | -0.27 |
| GROUP III | | 0.82 | 0.73 | -0.74 | -0.47 | -0.51 | -0.34 | -0.50 | -0.53 | -0.41 |
| ALL SUBJECTS | | 0.30 | 0.17 | -0.33 | -0.18 | -0.15 | -0.18 | -0.30 | -0.25 | -0.30 |

The relationship between the HHIE, the PTA, and the threshold and suprathreshold speech measures was examined. The results of the Pearson Product Moment correlation (seen in Table 17) show no strong correlation between the HHIE and the audiometric scores. The lack of correlation between the speech threshold measure, i.e. the SRT, once again illustrates the fact that the HHIE does not appear to be sensitivity weighted. Interestingly, there is also no relationship between the HHIE and the suprathreshold measures. This causes one to question whether the HHIE does, in fact, reflect handicap. It would seem that this scale is not asking questions which are related to everyday communication problems.

Since the performance of the Ss on the suprathreshold tasks did appear to be age dependent (i.e. the scores of Group III were found to be significantly different from those of Groups I and II), the correlation between the audiometric measures and the HHIE was also investigated for each of the age groups individually. Groups I and II followed the trend of the sample as a whole - there was no significant correlation between the HHIE and the audiometric measures. Group III, however, differed from the general trend in that this group demonstrated a strong positive relationship between the HHIE and threshold measures (PTA and SRT), and a slightly smaller, negative relationship with the monosyllabic word discrimination score. This relationship between the PTA, SRT and CID W-22 and the HHIE is in direct contrast to that reported by Berkowitz and Hochberg (1971) for the HHS. They reported a good correlation for these audiometric measures and the HHS for their 60 to 69 year old Ss, but no correlation for their Ss aged 80 years

and older. However, the results of the present study are not unlike those of Weinstein and Ventry (1983), who found significant correlation between the HMS and both threshold measures (PTA and SRT) and discrimination scores (CID W-22), with the latter correlation being lower than the others. Although in their study this was true for all the Ss, and not only those older than 80. The correlation between the HHIE and the threshold measures indicate that, for this group, the HHIE does appear to be sensitivity weighted. Examination of the PTA scores for Group III showed that all Ss with a loss exceeding 40 dB reported some degree of handicap, and no Ss reported handicap if the loss was less than 40 dB. This may be due to the fact that the mean PTA score for this group is slightly higher than for the others.

The lack of correlation between the other speech measures and the HHIE for all three groups brings into question the validity of the HHIE as a measure of handicap.

Tyler and Smith (1983) have suggested that this lack of correlation between handicap scales and speech identification may be due to the fact that the speech tasks that are used are not representative of everyday listening conditions. While this argument may hold for tests of monosyllabic discrimination in quiet, the other tasks would appear to be more representative of the less than ideal real life communication settings. Thus, it would seem to imply that the HHIE is not accurately reflecting handicap, although the SPIN and CSPIN tasks may not necessarily be an accurate reflection of communicative difficulty or handicap. The fact that Group III did

show a correlation between speech discrimination and the HHIE may reflect the complex age/hearing loss interaction seen in their performance on the various speech tasks, especially when considering that handicap (according to ASHA, 1981) is not determined by any one particular factor, but by the interaction of many.

The low false positive rate found in the present investigation, and the fact that the HHIE seems to be sensitivity weighted for those Ss aged 80 and older, suggest that it could possibly be used to identify those individuals who need audiological assessments. As far as the priority system, suggested by Ventry and Weinstein, is concerned, it needs to be modified so that all Ss who do not pass both the pure tone screener AND the HHIE are referred for further examination. In this way, all those individuals with moderate hearing loss, regardless of perceived handicap, as well as those who report some degree of handicap (as measured by the HHIE), regardless of the audiometric threshold, would be referred. Thus, rather than having a ranked priority system, the five priorities would essentially receive the same weighting, and the danger of under-referral would be obviated. However, until it is established exactly what the HHIE is measuring, and how this relates to actual handicap, it is difficult to estimate the degree of over-referral. This is possibly an aspect that needs further investigation.

# CHAPTER 5

## CONCLUSIONS

The characteristic hearing loss seen in all data on age-related pure tone sensitivity decline, viz. a gradually sloping, high-frequency, sensorineural loss was also seen in the present study. However, the mean threshold values were found to be greater than those reported in the literature. This was felt to be a reflection of the subject selection criteria employed in this study. Comparison of the mean thresholds for each age group provides evidence of a continuing sensitivity decline with increasing age. A similar trend was seen for the SRT scores, which showed good agreement with the PTA values. Administration of the pure tone tests was problematic in that the Ss responded more slowly and less consistently than to the other tests. This needs to be kept in mind in the clinicial situation, i.e. when testing elderly clients, the clinician should be prepared to spend more time administering the pure tone audiogram so that the results are not compromised.

Static compliance values and tympanogram shapes did not differ from those of normal young subjects. The pure tone ARTs did not appear to be affected by age, although a high percentage of reflexes at 4000 Hz were found to be absent. The BBN reflex was elicited at elevated levels, and was influenced by both age and hearing loss.

Interesting results, with important clinical and research implications, were found for the suprathreshold speech tasks. The important factor in differentiating between the Ss in terms of

their performance on these tasks was age, rather than audiogram configuration. Scores obtained by Group III for all the speech tests were found to be significantly different from those of Groups I and II. No significant difference was seen between the groups classified according to audiogram shape, although this should be confirmed with a larger group of Ss, with the Ss more evenly distributed between the groups. The possibility of qualititative, rather than quantitative, differences also needs to be examined.

There appeared to be a complex interaction between age and degree of loss. While Group III's significantly poorer performance could partially be explained on the basis of poorer hearing thresholds, the fact that their PTA scores did not differ significantly from those of Group II, and that these two groups did differ significantly from Group I, indicates that the reduced performance is ceused by the interaction of age and hearing loss. Further research into this relationship and determination of the degree of loss, above which an age effect can be expected, would be of great value in the clinical situation. This knowledge would help to clarify the concept of phonemic regression and therefore diagnostic accuracy would be improved.

Performance for all the Ss was best on the test of monosyllabic discrimination in quiet. The majority had scores which were better than 91%, thus contra-indicating the idea of disproportionately poor speech discrimination skills necessarily being associated with age-related hearing loss. When an elderly individual has dispropor-

tionately poor speech discrimination this should not be considered to be the norm, but should indicate the need for an indepth audiological assessment, as would be the case with younger clients.

With the exception of the HP items for the SPIN and CSPIN tests, speechscore variation was found to be significant within all three age groups, indicating that different aspects of auditory function are being measured. The primary complaint of many elderly individuals is the problems which they experience in understanding speech in noise, consequently assessment of speech discrimination in noise should form an essential part of both the routine audiological test battery and the hearing aid evaluation procedure. While the SPIN test does give an estimation of discrimination in noise, it is lengthy, so for the purposes of hearing aid evaluation where the clinician would be interested in a number of aided and unaided measures, it would not be the most suitable procedure. Procedures such as those described by Hagerman (1984), Dirks et al (1982) and Plomp and Mimpen (1979a; 1979b), which determine speech threshold for sentences or words as a function of the signal-to-noise ratio, would be more suitable. The clinical uitility of such procedures with the elderly population needs to be examined.

The importance of context in overcoming the effects of distortion (time-compression and noise) was illustrated by the lack of significant difference between the HP items of the SPIN and CSPIN tests. The clinical implication of this is that in the rehabilitation process more emphasis should be placed on context. The focus should be on teaching the elderly client skills which are

related to the utilization of context, and excrcises aimed at improving discrimination of individual words or syllables should be de-emphasised. Information concerning the extent to which an individual makes use of contextual clues is essential in planning rehabilitation. The SPIN and CSPIN tests provide such information and thus should be included in the aural rehabilitation test battery.

The question of central processing problems being a feature of age-related hearing disorders has not been resolved. All the Ss performed poorly on the LP items of the CSPIN test, in comparison with normal young listeners, which could be a reflection of CANS disorder. However, performance on the LP items of the SPIN test was poorer than for the CSPIN. The relative contribution of central processing to the reduced performance can only be determined once the performance of Ss with documented CANS disorders on these two tests has been evaluated.

The HHIE did not show a good correlation with audiometric measures, although there was a correlation between the PTA, SRT and CID W-22 discrimination for the Ss in Group III. The lack of correlation between the other speech measures and the HHIE would seem to suggest that it does not provide an accurate index of handicap. However, the results might have been influenced by the way in which the scale was administered, and by the fact that none of the Ss in the sample had a severe hearing loss. The scale may provide a more accurate reflection of handicap in a larger sample of Ss with a wider range of loss, and if the Ss were to complete the question-

naire themselves. Since the scale is very quick and easy to administer, and was found to have a low false positive rate, it is suggested that it be used in conjunction with a pure tone screening test in order to identify elderly individuals who may be in need of audiological services. It is suggested that individuals who fail either the screening test, or who indicate handicap on the HHIE, be referred for further evaluation.

In conclusion, it would appear that the effects of age on auditory function are complex, and that the elderly population is not a homogenous group. Further research into the effects of aging on auditory behaviour and communication ability is needed to improve our understanding of the problems experienced by aging listeners.

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APPENDIX "A"

NAME _____ DATE OF BIRTH: _____

HEARING HANDICAP INVENTORY FOR THE ELDERLY

| | YES (4) | SOMETIMES (2) | NO (0) |
|---|---|---|---|
| 1. (E-1) Does a hearing problem cause you to feel embarrassed when meeting new people? | | | |
| 2. (E-2) Does a hearing problem cause you to feel frustrated when talking to members of your family (/friends)? | | | |
| 3. (S-1) Do you have difficulty hearing when someone speaks in a whisper? | | | |
| 4. (E-3) Do you feel handicapped by a hearing problem? | | | |
| 5. (S-2) Does a hearing problem cause you difficulty when visiting friends, relatives or neighbours (or being visited by)? | | | |
| 6. (S-3) Does a hearing problem cause you to attend religious services less often than you like? | | | |
| 7. (S-4) Does a hearing problem cause you difficulty when listening to TV or radio? | | | |
| 8. (E-4) Does a hearing problem cause you to have arguments with family members? | | | |
| 9. (E-5) Do you feel that any difficulty with your hearing limits or hampers your personal or social life? | | | |
| 10. (S-5) Does a hearing problem cause you difficulty when in a restaurant (diningroom) with relatives or friends? | | | |

# APPENDIX "B"

## SPIN TEST SENTENCE LIST 1

(H) 1. The watchdog gave a warning growl.
(H) 2. She made the bed with clean sheets.
(L) 3. *The old man* discussed the dive.
(L) 4. Bob heard Paul called about the strips.
(L) 5. I should have considered the map.
(H) 6. The old train was powered by steam.
(H) 7. *He caught the fish* in his net.
(L) 8. Miss Brown shouldn't discuss the sand.
(H) 9. Close the window to stop the draft.
(H) 10. My T.V. has a twelve-inch screen.
(L) 11. They might have considered the hive.
(L) 12. David has discussed the dent.
(H) 13. The sandal has a broken strap.
(H) 14. The boat sailed along the coast.
(H) 15. Crocodiles live in muddy swamps.
(L) 16. *He can't* consider the crib.
(H) 17. The farmer harvested his crop.
(H) 18. All the flowers were in bloom.
(L) 19. I am thinking about the knife.
(L) 20. *David does not* discuss the hug.
(H) 21. She wore a feather in her cap.
(L) 22. We've been discussing the crates.
(L) 23. Miss Black knew about the doll.
(H) 24. *The Admiral* commands the fleet.
(L) 25. She couldn't discuss the pine.
(L) 26. Miss Black thought about the leg.
(H) 27. The beer drinkers raised their mugs.
(H) 28. He was hit by a *poisoned* dart.
(H) 29. *The bread was* made from whole wheat.
(L) 30. Mr Black knew about the pad.
(L) 31. You heard Jane called about the van.
(H) 32. I made the phone call from a booth.
(L) 33. *Tom wants to know* about the cake.
(L) 34. She's spoken about the bomb.
(H) 35. The cut on his knee formed a scab.
(L) 36. We hear you called about the lock.

(L) 37. The old man discussed the yell.
(H) 38. His boss made him work like a slave.
(H) 39. *The farmer hated the* boy.
(L) 40. They're glad we heard about the track.
(H) 41. A termite looks like an ant.
(H) 42. Air mail requires a special stamp.
(H) 43. *Football is a dangerous* sport.
(L) 44. Sue was interested in the bruise.
(L) 45. Ruth will consider the hard.
(H) 46. We saw a flock of wild geese.
(L) 47. The girl talked about the gift.
(L) 48. *Paul can't* discuss the wax.
(H) 49. Drop the coin through the slot.
(L) 50. I hope Paul asked about the mate.

## SPIN TEST SENTENCE LIST - 2

(L) 1. *You're* glad they heard about the slave.
(L) 2. The girl knows about the swamps.
(H) 3. Hold the baby on your leg.
(H) 4. *For your birthday I baked a* cake.
(H) 5. *The railroad* train ran off the track.
(L) 6. They did not discuss the scream.
(L) 7. They were interested in the strap.
(H) 8. Tear off some paper from the pad.
(L) 9. *I had a problem* with the bloom.
(L) 10. Peter should speak about the mugs.
(H) 11. The fruit was shipped in wooden crates.
(H) 12. The rancher rounded up his herd.
(L) 13. She wants to *speak* about the ant.
(L) 14. We're discussing the sheets.
(L) 15. The boy would discuss the scab.
(H) 16. The lonely bird searched for its mate.
(L) 17. Tom could have thought about *the sport*.
(L) 18. *You'd been* considering the geese.
(H) 19. They drank a whole bottle of gin.
(H) 20. On the beach we play in the sand.
(L) 21. Mr. Black considered the fleet.
(H) 22. *The airplane went into a dive*.
(H) 23. We're lost so let's look at the map.
(L) 24. I want to know about the crop.
(H) 25. Household goods are moved in a van.
(H) 26. The honey bees swarmed round the hive.
(L) 27. Betty has talked about the draft.
(L) 28. Tom discussed the hay.
(L) 29. Jane was interested in the stamp.
(H) 30. The airplane dropped a bomb.
(H) 31. *Put the bacon into* strips.
(L) 32. I had not thought about the growl.
(H) 33. The drowning man let out a yell.
(H) 34. I gave her a kiss and a hug.
(L) 35. *Paul should know about the* net.
(H) 36. I cut my finger with a knife.

(H) 37. The candle flame melted the wax.
(L) 38. Tom heard Jane called about the booth.
(L) 39. He can't consider the wheat.
(H) 40. This key won't fit in the lock.
(L) 41. *We have not discussed the* stamp.
(L) 42. Miss Brown might consider the coast.
(L) 43. Mr. Brown can't discuss the slot.
(H) 44. The little girl cuddled her doll.
(H) 45. Tom fell down and got a bad bruise.
(L) 46. *He hasn't* considered the dart.
(H) 47. The furniture was made of pine.
(H) 48. How did your car get that dent?
(L) 49. Mr. Smith thinks about the cap.
(H) 50. *The baby* slept in his crib.

# APPENDIX "B"

## SPIN TEST SENTENCE LIST - 1

(H) 1. The watchdog gave a warning growl.
(H) 2. She made the bed with clean sheets.
(L) 3. The old man discussed the dive.
(L) 4. Bob heard Paul called about the strips
(L) 5. I should have considered the map.
(H) 6. The old train was powered by steam.
(H) 7. He caught the fish in his net.
(L) 8. Miss Brown shouldn't discuss the sand.
(H) 9. Close the window to stop the draft.
(H) 10. My T.V. has a twelve-inch screen.
(L) 11. They might have considered the hive.
(L) 12. David has discussed the dent.
(H) 13. The sandal has a broken strap.
(H) 14. The boat sailed along the coast.
(H) 15. Crocodiles live in muddy swamps.
(L) 16. He can't consider the crib.
(H) 17. The farmer harvested his crop.
(H) 18. All the flowers were in bloom.
(L) 19. I am thinking about the knife.
(L) 20. David does not discuss the hug.
(H) 21. She wore a feather in her cap.
(L) 22. We've been discussing the crates.
(L) 23. Miss Black know about the doll.
(H) 24. The Admiral commands the fleet.
(L) 25. She couldn't discuss the pine.
(L) 26. Miss Black thought about the lap.
(H) 27. The beer drinkers raised their mugs.
(H) 28. He was hit by a poisoned dart.
(H) 29. The bread was made from whole wheat.
(L) 30. Mr Black know about the pad.
(L) 31. You heard Jane called about the van.
(H) 32. I made the phone call from a booth.
(L) 33. Tom wants to know about the cake.
(L) 34. She's spoken about the bomb.
(H) 35. The cut on his knee formed a scab.
(L) 36. We hear you called about the lock.
(L) 37. The old man discussed the yell.
(H) 38. His boss made him work like a slave.
(H) 39. The farmer baled the hay.
(L) 40. They're glad we heard about the track.
(H) 41. A termite looks like an ant.
(H) 42. Air mail requires a special stamp.
(H) 43. Football is a dangerous sport.
(L) 44. Sue was interested in the bruise.
(L) 45. Ruth will consider the herd.
(H) 46. We saw a flock of wild geese.
(L) 47. The girl talked about the gin.
(L) 48. Paul can't discuss the wax.
(H) 49. Drop the coin through the slot.
(L) 50. I hope Paul asked about the mate.

## SPIN TEST SENTENCE LIST - 2

(L) 1. You're glad they heard about the slave.
(L) 2. The girl knows about the swamps.
(H) 3. Hold the baby on your lap.
(H) 4. For your birthday I baked a cake.
(H) 5. The railroad train ran off the track.
(L) 6. They did not discuss the screen.
(L) 7. They were interested in the strap.
(H) 8. Tear off some paper from the pad.
(L) 9. I had a problem with the bloom.
(L) 10. Peter should speak about the mugs.
(H) 11. The fruit was shipped in wooden crates.
(H) 12. The rancher rounded up his herd.
(L) 13. She wants to speak about the ant.
(L) 14. We're discussing the sheets.
(L) 15. The boy would discuss the scab.
(H) 16. The lonely bird searched for its mate.
(L) 17. Tom could have thought about the sport.
(L) 18. You'd been considering the geese.
(H) 19. They drank a whole bottle of gin.
(H) 20. On the beach we play in the sand.
(L) 21. Mr. Black considered the fleet.
(H) 22. The airplane went into a dive.
(H) 23. We're lost so let's look at the map.
(L) 24. I want to know about the crop.
(H) 25. Household goods are moved in a van.
(H) 26. The hancy bees swarmed round the hive.
(L) 27. Betty has talked about the draft.
(L) 28. Tom discussed the hay.
(L) 29. Jane was interested in the stamp.
(H) 30. The airplane dropped a bomb.
(H) 31. Cut the bacon into strips.
(L) 32. I had not thought about the growl.
(H) 33. The drowning man let out a yell.
(H) 34. I gave her a kiss and a hug.
(L) 35. Paul should know about the net.
(H) 36. I cut my finger with a knife.
(H) 37. The candle flame melted the wax.
(L) 38. Tom heard Jane called about the booth.
(L) 39. We can't consider the wheat.
(H) 40. This key won't fit in the lock.
(L) 41. We have not discussed the steam.
(L) 42. Miss Brown might consider the coast.
(L) 43. Mr. Brown can't discuss the slot.
(H) 44. The little girl cuddled her doll.
(H) 45. Tom fell down and got a bad bruise.
(L) 46. He hasn't considered the dart.
(H) 47. The furniture was made of pine.
(H) 48. How did your car get that dent?
(L) 49. Mr. Smith thinks about the cap.
(H) 50. The baby slept in his crib.

## SPIN TEST SENTENCE LIST - 3

(H) 1. A rose bush has prickly thorns.
(L) 2. We should have considered the juice.
(H) 3. The shipwrecked sailors built a raft.
(L) 4. Bob could have known about the spoon.
(H) 5. Ruth poured the water down the drain.
(H) 6. The boy gave the football a kick.
(L) 7. Bill might discuss the foam.
(H) 8. The cop wore a bullet-proof vest.
(L) 9. Tom could not discuss the barn.
(L) 10. You were considering the gang.
(H) 11. After his bath he wore a robe.
(L) 12. Nancy should consider the fist.
(H) 13. I can't guess so give me a hint.
(H) 14. The soup was served in a bowl.
(L) 15. I've spoken about the pile.
(L) 16. Jane has a problem with the coin.
(H) 17. The bomb exploded with a blast.
(L) 18. Mary could not discuss the tack.
(L) 19. They have a problem with the limb.
(L) 20. Nancy had considered the sleeves.
(H) 21. Lubricate the car with grease.
(H) 22. The workers are digging a ditch.
(L) 23. Bill heard Tom called about the coach.
(H) 24. They marched to the beat of the drum.
(H) 25. No one was injured in the crash.
(L) 26. The old man thinks about the mast.
(H) 27. The sailor swabbed the deck.
(L) 28. Tom will discuss the swan.
(L) 29. Ann was interested in the breath.
(H) 30. This nozzle sprays a fine mist.
(L) 31. Ruth hopes he heard about the hips.
(L) 32. Tom is talking about the fee.
(L) 33. Miss Smith considered the scare.
(H) 34. The ship's Captain summoned his crew.
(H) 35. They fished in the babbling brook.
(H) 36. The hockey player scored a goal.
(L) 37. David should consider the blame.
(H) 38. They played a game of cat and mouse.
(L) 39. He's glad you called about the jar.
(L) 40. Tom will discuss the cot.
(H) 41. The steamship left on a cruise.
(H) 42. She faced them with a foolish grin.
(L) 43. He hopes Tom asked about the bar.
(L) 44. Miss Black could have discussed the rope.
(H) 45. A chimpanzee is an ape.
(H) 46. He wiped the sink with a sponge.
(H) 47. We shipped the furniture by truck.
(L) 48. Ruth's Grandmother discussed the bar.
(L) 49. I've been considering the crown.
(H) 50. A bear has a thick coat of fur.

## SPIN TEST SENTENCE LIST - 4

(L) 1. I want to speak about the crash.
(H) 2. Harry slept on the folding cot.
(L) 3. She's glad Jane asked about the drain.
(H) 4. The doctor charged a low fee.
(L) 5. He had considered the robe.
(L) 6. I haven't discussed the sponge.
(H) 7. The guilty one should take the blame.
(L) 8. You cannot have discussed the grease.
(H) 9. The cookies were kept in a jar.
(H) 10. Let's invite the whole gang.
(L) 11. Mr. White discussed the cruise.
(H) 12. The sport shirt has short sleeves.
(L) 13. They knew about the fur.
(L) 14. We've spoken about the truck.
(H) 15. The cushion was filled with foam.
(H) 16. How long can you hold your breath?
(L) 17. She wants to talk about the crew.
(H) 18. The cow was milked in the barn.
(H) 19. That accident gave me a scare.
(H) 20. The kitten climbed out on a limb.
(L) 21. You're glad she called about the bowl.
(L) 22. The man could not discuss the mouse.
(H) 23. He tossed the drowning man a rope.
(L) 24. You hope they asked about the vest.
(L) 25. You want to talk about the ditch.
(H) 26. Stir your coffee with a spoon.
(L) 27. We hear she called about the drum.
(H) 28. Bob stood with his hands on his hips.
(H) 29. The teacher sat on a sharp tack.
(L) 30. She might have discussed the ape.
(H) 31. The storm broke the sailboat's mast.
(H) 32. At breakfast he drank some juice.
(H) 33. He hit me with a clenched fist.
(L) 34. Peter knows about the raft.
(L) 35. The old man considered the kick.
(L) 36. We have not thought about the hint.
(H) 37. The team was trained by their coach.
(L) 38. Bill hopes Paul heard about the mast.
(H) 39. The king wore a golden crown.
(H) 40. The sand was heaped in a pile.
(L) 41. The boy can't talk about the thorns.
(L) 42. Miss Brown will speak about the grin.
(H) 43. The duck swam with the white swan.
(H) 44. Let's decide by tossing a coin.
(L) 45. She has a problem with the goal.
(L) 46. Jane didn't think about the brook.
(L) 47. He hears she asked about the deck.
(H) 48. He got drunk in the local bar.
(H) 49. The girl swept the floor with a broom.
(L) 50. The class will consider the blast.

## SPIN TEST SENTENCE LIST - 5

(L) 1. Miss White would consider the mold.
(I) 2. *Ruth has a problem with the joints.*
(L) 3. The boy might consider the bran.
(H) 4. To store his wood he built a shed.
(H) 5. *The lion gave an angry roar.*
(L) 6. He is considering the throat.
(L) 7. They hope he heard about the rent.
(H) 8. The car was parked at the curb.
(L) 9. Peter should consider the bow.
(L) 10. The old woman discussed the thief.
(H) 11. A round hole won't take a square peg.
(L) 12. You're discussing the plot.
(L) 13. The woman knew about the lid.
(H) 14. Peter dropped in for a brief chat.
(L) 15. You were interested in the scream.
(H) 16. The gambler lost the bet.
(H) 17. The burglar escaped with the loot.
(L) 18. He could discuss the bread.
(H) 19. He was scared out of his wits.
(L) 20. He doesn't discuss the map.
(H) 21. Eve was made from Adam's rib.
(H) 22. Get the bread and cut on a slice.
(L) 23. Bill won't consider the brat.
(H) 24. We heard the ticking of the clock.
(H) 25. Greet the heroes with loud cheers.
(H) 26. This camera is out of film.
(L) 27. Ruth wants to speak about the sling.
(H) 28. My jaw aches when I chew gum.
(L) 29. The man could consider the spool.
(H) 30. The bloodhound followed the trail.
(H) 31. The doctor prescribed the drug.
(H) 32. He rode off in a cloud of dust.
(L) 33. *He was interested in the hedge.*
(L) 34. Ruth hopes she called about the junk.
(H) 35. Playing checkers can be fun.
(L) 36. *We're glad Ann asked about the fudge.*
(H) 37. The super highway has six lanes.
(H) 38. Unlock the door and turn the knob.
(L) 39. Ruth is speaking about the meal.
(H) 40. Maple syrup is made from sap.
(L) 41. Bill cannot consider the dam.
(L) 42. We are speaking about the prize.
(H) 43. The car drove off the steep cliff.
(L) 44. Miss Smith couldn't discuss the row.
(H) 45. The glass had a chip on the rim.
(H) 46. Old metal cans were made with tin.
(L) 47. Miss White thinks about the tea.
(L) 48. *Miss White doesn't discuss the crumb.*
(H) 49. That job was an easy task.
(L) 50. Mr. White spoke about the firm.

## SPIN TEST SENTENCE LIST - 6

(H) 1. Throw out all this useless junk.
(H) 2. She cooked him a hearty meal.
(H) 3. Her entry should win first prize.
(L) 4. Ruth could have discussed the wits.
(L) 5. We could discuss the dust.
(H) 6. The stale bread was covered with mold.
(H) 7. The fireman heard her frightened scream.
(L) 8. We spoke about the knob.
(H) 9. Your knees and your elbows are joints.
(H) 10. I ate a piece of chocolate fudge.
(L) 11. Paul hopes we heard about the loot.
(H) 12. Instead of a fence, plant a hedge.
(H) 13. The story had a clever plot.
(L) 14. David might consider the fun.
(H) 15. The landlord raised the rent.
(L) 16. Paul could not consider the rim.
(L) 17. He heard they called about the lanes.
(H) 18. Her hair was tied with a blue bow.
(L) 19. They had a problem with the cliff.
(H) 20. He's employed by a large firm.
(L) 21. Harry will consider the trail.
(L) 22. We are considering the cheers.
(H) 23. To open the jar, twist the lid.
(L) 24. She has known about the drug.
(L) 25. Bill has a problem with the chat.
(L) 26. We hear they asked about the shed.
(H) 27. *The swimmer's leg got a bad cramp.*
(L) 28. Jane had not considered the film.
(H) 29. Our seats were in the second row.
(L) 30. *Jane did not speak about the slice.*
(L) 31. Paul was interested in the sap.
(L) 32. I am discussing the task.
(H) 33. *The thread was wound on a spool.*
(H) 34. They tracked the lion to his den.
(L) 35. Ruth has discussed the peg.
(H) 36. Spread some butter on your bread.
(L) 37. Tom is considering the clock.
(L) 38. He's thinking about the roar.
(H) 39. *A spoiled child is a brat.*
(L) 40. I should have known about the gum.
(H) 41. Keep your broken arm in a sling.
(H) 42. *The mouse was caught in the trap.*
(L) 43. They heard I asked about the bet.
(H) 44. I've got a cold and a sore throat.
(L) 45. Betty doesn't discuss the curb.
(L) 46. He had a problem with the tin.
(H) 47. Ruth poured herself a cup of tea.
(H) 48. The house was robbed by a thief.
(L) 49. He wants to know about the rib.
(H) 50. Wash the floor with a mop.

SPIN TEST SENTENCE LIST - 7

(L) 1. I did not know about the chunks.
(H) 2. The chicken pecked corn with its beak.
(L) 3. Bob could consider the pole.
(H) 4. The judge is sitting on the bench.
(L) 5. Mr. Smith knew about the bay.
(L) 6. You've considered the seeds.
(H) 7. The heavy rain caused a flood.
(H) 8. For dessert he had apple pie.
(L) 9. She hopes Jane called about the calf.
(H) 10. The detectives searched for a clue.
(L) 11. Mary hasn't discussed the blade.
(H) 12. The chicks followed the mother hen.
(L) 13. Mr. Brown thinks about the vault.
(L) 14. Bob was considering the clerk.
(H) 15. We camped out in our tent.
(H) 16. Paul took a bath in the tub.
(L) 17. Mary can't consider the tide.
(L) 18. The old man talked about the lungs.
(H) 19. The candle burned with a bright flame.
(H) 20. My son has a dog for a pet.
(L) 21. Bob has discussed the splash.
(H) 22. The plow was pulled by an ox.
(H) 23. The flood took a heavy toll.
(L) 24. Mr. Smith spoke about the aid.
(L) 25. Mary had considered the spray.
(H) 26. The pond was full of croaking frogs.
(L) 27. The girl should not discuss the gown.
(H) 28. Please wipe your feet on the mat.
(L) 29. Ruth hopes Bill called about the cop.
(L) 30. We will consider the debt.
(L) 31. Peter could consider the dove.
(H) 32. She shortened the hem of her skirt.
(H) 33. The cabin was made of logs.
(L) 34. Bill can't have considered the wheels.
(L) 35. He has a problem with the oath.
(H) 36. The dealer shuffled the cards.
(H) 37. The shepherd watched his flock of sheep.
(H) 38. The flashlight casts a bright beam.
(L) 39. We could consider the feast.
(H) 40. The scarf was made of shiny silk.
(H) 41. The guests were welcomed by the host.
(L) 42. Betty has considered the bark.
(H) 43. The sick child swallowed the pill.
(L) 44. Paul should have discussed the flock.
(H) 45. Tighten the belt by a notch.
(L) 46. She might discuss the crumbs.
(L) 47. Tom has not considered the glue.
(H) 48. The swimmer dived into the pool.
(L) 49. Tom has been discussing the beads.
(H) 50. Follow this road around the bend.

SPIN TEST SENTENCE LIST - 8

(H) 1. The bird of peace is the dove.
(L) 2. Tom had spoken about the pill.
(H) 3. The cigarette smoke filled his lungs.
(L) 4. They've considered the sheep.
(H) 5. Cut the meat into small chunks.
(H) 6. Watermelons have lots of seeds.
(L) 7. The man should discuss the ox.
(L) 8. Miss Smith knows about the tub.
(H) 9. Raise the flag up the pole.
(L) 10. Peter has considered the nut.
(H) 11. The bride wore a white gown.
(L) 12. She might consider the pool.
(H) 13. We swam at the beach at high tide.
(H) 14. The poor man was deeply in debt.
(L) 15. She's glad Bill called about the desk.
(L) 16. Harry had thought about the logs.
(H) 17. Banks keep their money in a vault.
(H) 18. The witness took a solemn oath.
(L) 19. Bill didn't discuss the hen.
(L) 20. Ruth must have known about the pie.
(H) 21. The shepherds guarded their flock.
(L) 22. Bob has considered the tent.
(L) 23. We're speaking about the toll.
(H) 24. A bicycle has two wheels.
(H) 25. Ann works in the bank as a clerk.
(L) 26. Tom won't consider the silk.
(H) 27. Ruth had a necklace of glass beads.
(L) 28. She's discussing the beam.
(H) 29. Paul hit the water with a splash.
(H) 30. The nurse gave him first aid.
(H) 31. The wedding banquet was a feast.
(L) 32. Nancy didn't discuss the skirt.
(L) 33. The girl should consider the flame.
(H) 34. Tree trunks are covered with bark.
(H) 35. Break the dry bead into crumbs.
(L) 36. Mr. Black has discussed the cards.
(L) 37. The woman considered the notch.
(L) 38. The man spoke about the clue.
(H) 39. The boat sailed across the bay.
(L) 40. I'm talking about the bench.
(L) 41. They heard I called about the pet.
(H) 42. The cow gave birth to a calf
(L) 43. I'm glad you heard about the bend.
(H) 44. It was stuck together with glue.
(L) 45. The woman talked about the frogs.
(H) 46. Bob was cut by the jackknife's blade.
(H) 47. Paul was arrested by the cops.
(L) 48. Bill heard we asked about the host.
(H) 49. Kill the bugs with this spray.
(L) 50. The class should consider the flood.

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**Name of thesis** Audiological correlates of aging. 1987

***PUBLISHER:***
**University of the Witwatersrand, Johannesburg**
**©2013**

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