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PSYCHOLOGICAL ASPECTS OF AUDITORY DISORDERS: COGNITIVE FUNCTIONING AND PSYCHOLOGICAL STATE.

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Do mo mhac Seosamh.

The data for Study Six of this thesis were collected by Ms L. Bach, a clinical psychology trainee, under my supervision.

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ABSTRACT

This thesis presents six studies concerned with the psychological status of people with audiological disorders, particularly tinnitus and hearing loss. Study One (Part I of the thesis) employed a structured interview and the General Health Questionnaire to investigate the emotional status of subjects with a variety of audiological symptoms. Psychological disorder was found to be more prevalent among subjects complaining of vertigo (64%) than among those complaining of tinnitus (45%); the prevalence of psychological disorder among subjects complaining of hearing loss was lower than among tinnitus subjects (27%). A higher prevalence of disturbance was found among subjects with multiple symptoms. A previous history of psychological distress correlated with current ratings of disturbance. Studies Two and Three (Part II) are concerned with the psychology of cochlear implantation. Methodological issues concerning psychological assessment in this context are discussed. Study Two uses Repertory Grid Technique to assess the psychological consequences of using an implant. Eight out of ten subjects reported important changes in psychological well-being related to their use of the device. Study Three identifies a group of subjects applying for an implant while having a non-organic hearing loss. The implications for the use of standardised assessment procedures are discussed. Studies Four, Five and Six (Part III) assess the cognitive functioning of subjects with tinnitus. Tinnitus subjects' performance on neuropsychological tests is compared with that of hearing impaired control subjects. Subjects were also assessed using the Cognitive Failures Questionnaire (CFQ). The emotional status of the subjects was assessed using the Speilberger State-Trait Anxiety Inventory. The Beck Depression Inventory was also used in Study Six. The groups were not distinguished by a number of neuropsychological tests, however it was found, in Studies Four and Five, that Tinnitus subjects' performance on verbal fluency tests was significantly poorer than the Control subjects, after hearing loss was controlled for. In Study Six it was found that both Tinnitus and Control subjects performed less well than expected on the STROOP test; this was more apparent in the Tinnitus group. The Tinnitus group also obtained higher CFQ scores in Studies Four and Five. Trait anxiety was a feature of the Tinnitus groups. The implications for the cognitive functioning of both tinnitus and hearing impaired subjects are discussed in terms of Baddeley's model of working memory. The importance of these findings for complaint about tinnitus and hearing loss are considered.

Chapter 1

GENERAL INTRODUCTION

This thesis presents six studies concerned with the psychological status of people with audiological disorders, particularly tinnitus and hearing loss. The thesis is divided into three parts. The first part is a study of psychological disturbance in patients with a variety of audiological disorders. Part II describes two studies concerning psychological issues related to surgery designed to restore some acoustical input to profoundly deafened people (i.e. cochlear implantation). Part III describes three studies into the cognitive functioning of people with tinnitus.

Historical background to the work.

Clinical psychology has been applied within medical and surgical fields outside of psychiatry for several decades, with clinical psychologists working in areas such as cardiac care, hypertension, pain management and obstetrics. The application of clinical psychology within the field of audiological medicine and its associated discipline otolaryngology, however, is comparatively new. In 1982 psychologists began to work in this area at the Royal National Throat Nose and Ear Hospital in London; they were among the first psychologists in the world to be involved in the field. They were employed to carry out research into the psychology of tinnitus. In late 1983 the author was appointed as a clinical psychologist to provide an assessment and treatment service to patients with all types of audiological disorder, most notably tinnitus, hearing loss and vertigo. The newness of the clinical work meant that numerous issues arose that demanded a systematic approach to the clinical service and there was necessarily a strong evaluative component to the work. This thesis is concerned with some of the theoretical and clinical issues that arose through these developments.

Tinnitus and Hearing Loss: Definitions and Epidemiology.

The thesis focuses on psychological issues relating to hearing loss and tinnitus, both of which are disorders of the ear. Hearing loss can arise through many different aetiologies. A basic distinction is made between hearing loss that is present at birth, or prelingually, and that which is acquired post lingually; the present research is concerned with only the latter type. Distinctions can also be made between conductive hearing loss and sensori-neural hearing loss. When the structures of the outer or middle ear are dysfunctional, the hearing loss is described as conductive in nature. Sensori-neural hearing loss arises as a result of cochlear (inner ear) dysfunction. Conductive hearing losses can be in the order of 50 to 60 dB HL; however, most hearing loss at 25 dB HL or greater is sensori-neural in nature. The issues addressed in this thesis relate to hearing loss of this type.

Tinnitus is the perception of noise in the absence of any external source and has for long been regarded as the result of cochlear dysfunction. Over the last decade a greater emphasis has been placed on the central, (i.e. brain) processing of cochlear pathology in the perception of tinnitus (Jastreboff, 1990). Like hearing loss, the symptom can have many and diverse aetiologies although it is common clinical practice to tell the patient that "whatever caused your hearing loss also caused your tinnitus". Tinnitus can be distressing and for the majority of people there are no practical medical or surgical solutions to the symptom.

The co-morbidity between hearing loss and tinnitus is high and many people are likely to experience distress as a result of both symptoms (Lindberg, Lyttkens, Melin & Scott, 1984). The National Study of Hearing conducted by the MRC Institute of Hearing Research (Davis, 1989) estimated that 16.1% of the adult population (aged 18-80 years) have a hearing disorder of 25 dB HL or greater. This means that there are about 7.7 million people in the UK with a hearing loss. As the severity of hearing impairment increases so the prevalence decreases. The prevalence of very profound hearing loss (95 dB HL or greater) is 0.2% of the population. The prevalence of hearing impairment at all levels of severity is dependent on age. Below the age of forty-five years even mild hearing loss is relatively rare (<5% of the population) but close to 50% of people aged 70 -74 years have a hearing loss of 25 dB HL or more. Some 30% of the population experience some degree of tinnitus, although usually very minor in nature. Ten per cent of the population report persistent spontaneous tinnitus, i.e. not just after exposure to noise, and nearly 7% of the population have consulted a doctor about tinnitus (Davis, 1993). Davis (1993) found that tinnitus correlated highly with the individual's hearing impairment and that the best predictor of tinnitus was the severity of hearing impairment. In summary, tinnitus and hearing loss are symptoms that affect large numbers of people and that often co-exist.

Introduction to the aims of this thesis.

There is an extensive literature on the emotional consequences of tinnitus and hearing loss. While it might be assumed, on *a priori* grounds, that hearing loss and tinnitus would be associated with psychological distress the empirical picture is mixed. In Part I of this thesis this relationship will be investigated by assessing the emotional state of patients with a variety of audiological disorders. In Part II the relationship will be investigated by assessing the psychological effects of cochlear implant surgery.

The cognitive functioning of patients with tinnitus represents a new field of study and will be investigated in Part III by comparing the performance of tinnitus patients with that of hearing impaired controls on a number of widely used neuropsychological tests. There is considerable overlap between the study of cognitive functioning and of the emotional status of people. This is because the study of cognitive functioning necessarily involves an assessment of other aspects of psychological state. The studies of cognitive functioning in Part III will therefore also contribute to the overall assessment of the emotional status of tinnitus and hearing impaired patients.

A brief overview of the literature will be presented here in order to outline the background to the issues studied in this thesis. Each of the areas of study will subsequently be introduced by a more specific review of the literature.

Overview of the literature.

1. Emotional Aspects of Hearing Loss.

The emotional effects of hearing loss have been investigated in a number of ways: by simulating hearing loss; by assessing the psychological status of people with a hearing loss; and by assessing the audiological profile of some psychiatric patients.

In order to investigate the psychological effects of hearing loss a number of researchers have sought to simulate the symptom in normally hearing subjects (Aplin & Kane, 1985; Eriksson-Mangold & Erlandsson, 1984; Hebb, Heath & Stuart, 1954; von der Lieth, 1973; Zimbardo, Andersen & Kabat, 1981). These studies have not proved particularly informative. While some negative emotional consequences have been described, the results are inconclusive; these studies have been restricted by the difficulty in achieving meaningful levels of hearing loss and by their temporary and artificial nature.

There are reports in the literature of negative consequences of hearing loss among clinical populations. Emotional problems like depression, neurotic symptoms, paranoia, social stress, insecurity, loneliness and social isolation have all been reported (e.g., Knapp, 1948; Mahapatra, 1974; Meadow-Orlans, 1985; Rousey, 1971; Schlesinger, 1985) pointing to a link between hearing loss and psychological disturbance. However, further consideration of the literature shows that the association between hearing loss and emotional state is more complex than it might seem.

Some studies have shown an association between hearing impairment and psychiatric complications (Cooper, Curry, Kay, Garside & Roth, 1974; Singerman, Riedner & Folstein, 1980), whereas others have found less or conflicting support for these findings (Cooper, Garside & Kay, 1976; Eastwood, Corbin, Reed, Nobbs & Kedward, 1985; Gilhome-Herbst & Humphrey, 1980; Thomas, Hunt, Garry, Hood, Goodwin & Goodwin, 1983). When other health problems are controlled for the correlations between hearing loss and anxiety and depression have been found to be weaker (Jones, Victor & Vetter 1984). Andersson, Melin, Lindberg and Scott (1995) studied older people with hearing impairment found that health factors, hearing problems and psychological factors clustered together. Thus both these studies point to the importance of other health problems in determining psychological status. The picture that emerges from the literature is therefore inconclusive; there is the suggestion that associated factors other than the specific symptom of hearing loss may be important in bringing about psychological distress. Further study is indicated and thus Part I of this thesis examines the link between psychological state and specific audiological symptoms and considers the importance of multiple symptoms.

The confusion in the literature is further highlighted by considering studies that examine the relationship between hearing loss and depression. In some studies the subjective experience of hearing impairment has been linked with depression (e.g. Andersson, Melin, Lindberg & Scott, 1995; Knutson & Lansing, 1990). Gilhome-Herbst and Humphrey (1980) reported a high prevalence of depression among a group of elderly hearing impaired subjects that appeared to be associated with social isolation. Thomas and Gilhome-Herbst (1980) suggested that in younger groups hearing loss is more associated with loneliness than isolation. They suggested that elderly people who were either active or disengaged from society were more depressed. The majority of people fell between these two extremes and were less handicapped and less depressed than their more active or more disengaged peers. These studies again suggest that poor psychological state might be related to factors other than hearing loss per se.

The link between audiological measures and psychological disturbance is also unclear. If hearing loss is associated with psychological disturbance then it might be expected that there would be a relationship between the extent of the hearing loss and the extent of the psychological problems. This expectation, however, does not receive strong support in the literature; a lack of a clear relationship between the extent of hearing loss and the extent of psychological disturbance has been a frequent observation (Thomas & Gilhome-Herbst, 1980; Gilhome-Herbst & Humphrey, 1980; Berrios, Ryley, Garvey & Moffat, 1988) However, Thomas and Gilhome-Herbst (1980) did identify psychological disturbance in a greater number of subjects with more severe hearing loss and poor speech discrimination. As part of the investigation of cognitive functioning of audiological patients an assessment of the association between the degree of hearing loss and anxiety will be included in Part III.

Conclusions drawn in review articles give an indication of the variability with which the psychological consequences of hearing impairment have been viewed over the years. Cooper (1976) found an over-representation of hearing-impaired individuals among samples of patients suffering from paranoid psychoses. Rosen (1979) concluded that it had not been established that the hearing impaired population differ from the general population on either psychiatric or psychological variables. Thomas (1981) concluded that acquired hearing impairment was associated with psychological disturbance. He found less support, however, for the notion that hearing impairment resulted in heightened suspiciousness or increased likelihood of paranoid reactions.

Subsequently, Thomas (1984) questioned whether hearing loss per se leads to psychological changes; he concluded that there was no evidence that hearing loss, in itself, should lead to a deterioration in psychological well being. Jakes (1988) concluded from his review of the literature that while not every hearing impaired person is emotionally disturbed, psychological disorder can occur with hearing loss and this disorder can be reduced if the hearing loss is alleviated. Jakes (1988) also pointed out that the majority of hearing impaired people do not complain to a doctor about their hearing and some people for whom there is audiometric evidence of hearing impairment do not report hearing loss. This observation again highlights the fact that the relationship between hearing impairment and psychological disturbance is complex. Jones and White (1990) concluded their review by noting that results on the consequences of hearing loss on personality were contradictory. They found support for a link between hearing loss and mood disorders but questioned the association between hearing impairment and paranoid illness. Andersson (1995) reviewed the literature and came to similar conclusions. The picture that emerges from the review articles is therefore again inconclusive.

Thomas (1984) criticised many studies for poor methodology. Issues surrounding the methodology of studying psychological factors in hearing impaired people will be discussed further in Parts I and II of this thesis.

The WHO (1980) classification of impairment, disability and handicap is helpful in understanding the lack of a clear relationship between the extent of hearing loss and the level of psychological disturbance. Impairment refers to the loss of basic function measurable in the clinic or the laboratory, disability is the loss of everyday auditory ability and handicap is the disadvantage that results. Handicap will depend upon the demands that are placed upon the individual and the extent to which the person is prevented from fulfilling particular roles. The WHO definitions invite a behavioural perspective in the assessment and treatment of hearing problems. The potential for a behavioural approach has been argued by McKenna (1987). Andersson (1995) also described the use of functional analysis and behavioural counselling as an approach to hearing tactics training - the strategies used by a person to overcome the everyday problems associated with the hearing loss. Apart from the influence of environmental constraints and demands it is conceivable that hearing loss will have differing effects on individuals as a result of personality differences.

High, Fairbanks and Glorig (1964) stated that "Two persons with identical hearing impairment will not necessarily suffer the same degree of handicap. Personality and emotional factors play a considerable role in the adjustment to physical impairment" (p.216). A link between personality and vulnerability to noise-induced hearing loss has been postulated. This was discussed by Jakes (1987; 1988). While links between Type A personality and noise-induced peripheral vasoconstriction, and between temporary threshold shift and vasoconstriction, have been demonstrated, no clear link has been established between Type A personality and hearing loss. Nonetheless, clinical observations suggest that psychological factors are involved in the illness behaviour of hearing impaired people and may disrupt their communication strategies, e.g. lip-reading. A number of studies (Gildston & Gildston, 1972; Ickes & Nader, 1982; Weir & Stephens, 1976) have examined the role of other personality factors in hearing impairmed people. Stephens (1980) used the Eysenck Personality Inventory and found elevated levels of neuroticism and introversion in hearing impaired people. Coren and Harland (1995) found that reduced hearing acuity was associated with increased neuroticism. The issue of personality traits in coping with hearing impairment will be addressed in Part III of this thesis.

It is possible that the relationship between hearing loss and psychological difficulties is more complex than many studies have allowed for. Andersson (1995) interpreted the link between hearing impairment and psychological distress from a diathesis-stress point of view. The link between the experience of audiological symptoms and other stress, and the individuals vulnerability to them, will be discussed in a number of chapters of this thesis.

The processes by which an individual copes with hearing loss have been discussed by Eriksson-Mangold (1991). She appealed to Bowlby's ideas (1980) and postulated that hearing loss may have an effect through an individual's need to develop cognitive maps in order to pursue goal oriented behaviour. The changes imposed by hearing loss may lead to inadequate or inaccurate cognitive models. She also highlighted the approach that points to loss of control as the central factor in producing psychological change in hearing impaired people. In a similar vein McDavis (1984) suggested that a sense of personal control is an important factor when facing hearing impairment. He hypothesised that internal control would lead to greater denial of hearing impairment in older adults. Personal control was found to be an important aspect of hearing impaired people's communication successes in a study by Scott, Lindberg, Melin and Lyttkens (1994). The importance of control in coping with hearing disorders will be discussed in a number of chapters.

2. The psychological effects of cochlear implantation.

Improvements in psychological functioning after partial restoration of hearing in patients, have been documented (Gildston & Gildston, 1972; Harless & McConnell, 1982; Mulrow, Aguilar, Endicott, et al., 1990; Stevens, 1982) again pointing to the importance of hearing for emotional well-being. The possibility of an entirely different approach to the investigation of the psychology of hearing has arisen with the development of cochlear implantation. This is a new surgical procedure to restore some acoustical input to otherwise profoundly deafened people. Cochlear implantation has been at the leading edge of bionic technology since the early 1980's. Much of the early psychological work in this area was concerned with the pre and post-operative evaluation of people using standardised measures of intelligence and personality. This served the useful role of establishing that electrical stimulation of the cochlear did not have any deleterious effects; unfortunately, it was not particularly informative in other ways. Knutson, Schartz, Gantz, Tyler, Hinrichs and Woodworth (1991), however, argued that there is a place for such tests and report modest changes on some measures. McKenna (1991) argued that caution should be exercised in the use of these instruments in this context. The appropriateness and value of assessment instruments that are standardised on normally hearing populations being used with cochlear implant patients will be discussed in Part II. There remains a need to assess the impact of cochlear implantation in a way that is meaningful for each individual patient; this will be a focus of Part II.

Ramsdell (1962) suggested that hearing served three different functions. These are: symbolic, primarily concerned with communication; warning; and the perception of background noise. His contention was that the perception of background noise keeps a person in touch with the world and that the loss of this function is the most important factor in producing depression in deafened people, i.e. that sensory deprivation is the central factor in producing psychological disturbance. Although Ramsdell's ideas have been widely quoted they have not been systematically tested. The psychological importance of modest improvements in hearing through the use of cochlear implants is examined in Part II.

3. Emotional Aspects of Tinnitus

In the field of tinnitus research a considerable amount of work has followed the pattern of research on hearing loss in that it has been concerned with the psychiatric classification of tinnitus patients (e.g. Singerman, Riedner & Folstein, 1980; Harrop-Griffiths, Katon, Dobie, Sakai & Russo, 1987; O'Connor, Hawthorn, Britten & Webber

1987; Berrios, Ryley, Garvey & Moffat, 1988). There are numerous descriptions of the negative consequences of tinnitus (e.g., Coles & Hallam, 1987; Fowler, 1948; Hallam, Rachman & Hinchcliffe, 1984; Tyler & Baker, 1983). It is important to note that there are large individual differences in the extent to which patients experience tinnitus related problems (Briner, Risey, Guth & Noris, 1990). The link between tinnitus and emotional distress has been investigated in several studies (e.g., Collet, Moussu, Disant, Ahami & Morgon, 1990; Halford & Anderson, 1991; Harrop-Griffiths et al., 1987; Kirsch, Blanchard, & Parnes, 1989; Simpson, Nedzelski, Barber & Thomas, 1988; Wood, Webb, Orchik & Shea, 1983). This link may appear more obvious to lay people than the association between hearing impairment and psychological distress. It should be noted that most studies on the emotional consequences of tinnitus have been conducted on highly selected samples of patients with severe tinnitus distress (e.g., Briner et al., 1990). Some studies have found relatively low (but significant) correlations between tinnitus distress and psychological complaints (Halford & Anderson, 1991; Hiller, Goebel & Rief, 1994). Simpson et al. (1988) found that 63% of tinnitus sufferers could be classified as psychiatrically disturbed and 46% had mood disorder as assessed by the Structured Interview for the DSM-III-R (SCID). A number of studies have used the Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock & Erbaugh, 1961) in the assessment of tinnitus patients. Kirsch et al. (1989) reported that the mean BDI score for a group of tinnitus patients was within the normal range. Wilson et al. (1991) and unpublished data from a Swedish population (Andersson, unpublished data) using larger samples revealed mean scores within the range of only mild mood disturbance. The psychological importance of tinnitus, however, is emphasised in the postulated link between the symptom and suicide (Lewis, Stephens & Huws, 1992; Lewis, Stephens & McKenna, 1994). In summary, the evidence from these studies for an association between tinnitus and psychological distress is mixed, with some studies showing no, or mild distress and others pointing to significant distress.

Erlandsson (1990) theorised that there were two psychological reactions to tinnitus; one characterised by anxiety and one by depression but these thoughts have not yet been empirically validated. In a review by Hinchcliffe and King (1992), depression was found to be the principal distinguishing feature between tinnitus complainers and non-complainers. The conclusion that must be drawn from the literature is that the link between tinnitus and psychological state is a complex one. It will be a focus of further study in Parts I and III of this thesis.

The personality of the tinnitus patient has also been the subject of some interest (e.g., Collet, Moussu, Disant, Ahami & Morgon, 1990; Gerber, Nehemkis, Charter & Jones, 1985; Reich & Johnson, 1984). While there is a common perception of the tinnitus patient as a "neurotic individual" the literature does not always support this view. For example, Collet et al. (1990) used the Minnesota Multiphasic Personality Inventory and found normal scores overall, with the exception of elevated depression scores in men. The importance of some personality factors in coping with tinnitus will be examined in Part III.

Psychologists have had a more concerted involvement in the field of tinnitus for a slightly longer period of time than has been the case for other otological symptoms. It is also the case that there are clear reasons to suspect a psychological component to tinnitus. The research focus has therefore been quicker to move on to psychological issues beyond whether or not tinnitus patients suffer from psychiatric symptoms.

4. Cognitive functioning of tinnitus patients.

Interest in the cognitive functioning of tinnitus patients stems from a number of sources including from consideration of the nature of the symptom.

As is the case with hearing loss, a far greater number of people experience tinnitus than regard it as a problem or seek help for it. In fact, it has been argued that tinnitus may be regarded as an almost universal experience. Heller and Bergman (1953) placed a series of normally hearing subjects in a sound proofed room and requested that they report anything that they heard. All subjects reported hearing some noises. Although some ten per cent of the population experience persistent tinnitus, only one per cent complain of considerable suffering as a result of tinnitus, and one half of one per cent experience major distress due to tinnitus (Davis, 1989). The simple presence of the symptom therefore does not mean that the person will experience distress.

Tinnitus is a phantom symptom with as yet no objective marker of its presence. Attempts can be made, however, to match a person's tinnitus to an external sound. Matching generally takes place in terms of frequency and loudness. Reed (1960) found that for the majority of people tinnitus was matched to very quiet sounds. Goodwin and Johnson (1980) allowed for the effects of loudness recruitment (i.e. when the growth of loudness above auditory threshold is abnormally large) at the tinnitus frequency and again found that for most people tinnitus matches were remarkably low (i.e. 30 dB SL or less). Tinnitus loudness is much lower than the level at which external noises are rated as annoying by most people. Furthermore, matching and masking levels are not good predictors of tinnitus discomfort (Hinchcliff & King, 1992). Hallam, Prasansuk and Hinchcliffe (1983) compared tinnitus sufferers with others who had the symptom but did not complain about it. Self reported loudness did not distinguish the two groups nor did a loudness match. Therefore, not only is the presence of tinnitus a poor indicator of distress, but also the intensity of tinnitus does not seem to account fully for the difficulties that might arise from it. This suggests that complaints about tinnitus may be psychologically determined.

Hallam et al. (1984) proposed that the natural history of tinnitus is characterised by the process of habituation, i.e. that habituation to tinnitus is the norm and that continued annoyance can be regarded as a failure of habituation to take place. They argued that habituation to tinnitus might be impeded by a number of factors; a high level of tonic arousal, tinnitus acquiring a strong emotive significance, particularly intense or unpredictable tinnitus, or a change in the tinnitus. The first two of these have implications for psychological therapy. What must be the largest single focus of research energy in this field has gone in to evaluating psychological therapies in the management of tinnitus patients. Andersson, Melin, Hagnebo, Scott and Lindberg (1995) have reviewed these studies. They conclude that the effects of psychological treatments were generally beneficial and that combined behavioural and cognitive approaches appear to be more successful than either alone. The extent of improvement, however, was often modest. Nonetheless, the fact that treatment studies have found beneficial effects of cognitive and behavioural interventions lends support to Hallam et al's (1984) model. More recently a parallel tinnitus model has been put forward by Jastreboff (1990) and by Jastreboff and Hazell (1993). In common with Hallam et al's (1984) model these authors emphased the emotional importance of the tinnitus signal. They also suggested that tinnitus perception involves not only cochlear pathology but also the central (i.e. brain) processing of the signal. They highlighted a number of brain structures, including limbic system areas and the prefrontal cortex, as of likely importance in this respect. These areas also subserve emotion (Lezak, 1983; Lishman, 1987) and as such their involvement in tinnitus perception may be regarded as implicit also in the earlier model by Hallam et al (1984). The importance of central factors in tinnitus perception has been recognised by other workers (e.g. Attias, Urbach, Gold & Sheemesh, 1993; Shiraishe, Sugimoto, Kubo, et al 1991). The emphasis on central factors in tinnitus perception draws attention to a feature of tinnitus complaint that hitherto has received little attention, i.e. difficulties in concentration.

Since the 1980's several studies (Tyler & Baker, 1983; Jakes, Hallam, Chambers, & Hinchcliffe, 1985; Hallam, Jakes & Hinchcliffe, 1988; Hiller & Gobel, 1992; Stephens, Lewis & Sanchez, 1993) have pointed to the multidimensional character of tinnitus complaints. Emotional distress, auditory perceptual difficulties (i.e. interference with hearing) and insomnia are repeatedly identified factors in studies of tinnitus complaint. Complaints about difficulties in cognitive functioning are common in a clinical setting. These complaints do feature among the difficulties listed in the above studies, however, to date there has been no systematic investigation of cognitive functioning in tinnitus patients. An investigation of this aspect of tinnitus complaint is the central focus of Part III.

Summary of Main Aims.

The study of psychological questions within the field of audiological medicine and otolaryngology continues with growing interest and application. The present work examines issues that were previously unaddressed and takes a new approach to matters that have been considered elsewhere.

The first area of concern (Part I) is a re-examination of the traditional psychiatric classification approach to hearing loss and tinnitus. Subjects complaining of hearing loss and tinnitus will be assessed from a clinical psychology perspective as well through the use of a psychiatric inventory. Subjects complaining of other neuro-otological symptoms, most notably vertigo, will also be examined for the sake of completeness. In this instance the clinical psychology approach will involve a structured interview that allows a more informed judgement to be made about patients than is possible simply from a questionnaire score.

The second area of interest (Part II) is in the psychological assessment of cochlear implant patients. There has been an obvious need for careful psychological evaluation of those undergoing this procedure and the psychological consequences of it will be explored in this thesis. This offers a hitherto rarely available possibility of assessing the effects of the restoration, rather than the loss, of some acoustical input. In addition, a small group of people requesting cochlear implantation while having non-organic hearing loss is identified and the implications for the debate about the use of standardised measures in this context will be discussed.

The third area of interest (Part III) is in the field of tinnitus. Complaints about disruption to "concentration, thinking or memory" are common among tinnitus sufferers. These complaints have implications for understanding the multidimensional nature of tinnitus and for the growing interest in central factors in its perception. This thesis includes studies of the cognitive functioning of tinnitus patients as measured on neuropsychological tests. In so doing it addresses an issue that has not previously been investigated in any systematic way. In order to put the neuropsychological test results into a proper context assessment of the emotional status of the subjects will be included.

PART I

Emotional disturbance in Neuro-Otology patients

Chapter 2

STUDY ONE

THE PREVALENCE OF PSYCHOLOGICAL DISTURBANCE IN NEURO-OTOLOGY OUTPATIENTS

Introduction

A number of studies have pointed to the high prevalence of psychiatric disturbance among patients seen in a general medical setting (MacGuire, Julier, Hawton & Bancroft, 1974; Hamilton, Campos & Creed, 1996), in general practice (Lloyd, Jenkins & Mann, 1996), and in specialist (non-psychiatric) settings such as ENT (Goldie, 1978), neurology (Bridges & Goldberg, 1984) and dermatology (Hughes, Barraclough, Hamblin & White, 1983). For reviews see Nabarro (1984), Mayou and Hawton (1986) and Anonymous (1979). It has been pointed out that over half of all the medical patients who are psychologically distressed may not be detected by the medical staff looking after them (Anonymous, 1979) and that the detection of 'psychiatric' problems in medical patients is important because many of these problems persist (Nabarro, 1979). Moreover, such problems in general hospital patients are often easily treated (Mayou & Hawton, 1986) and a failure to recognise psychological problems leads to an expensive waste of resources in terms of investigations and unsuccessful physical treatments (Saperia, 1984; Rose, Smith & Troughton, 1984). In fact, the amount of treatment given to patients for their physical problems may be influenced more by their distress and illness behaviour than by the severity of their physical disease (Waddell, Main, Morris, Di Paola, & Gray, 1984). Several authors (Querido, 1959; Stavraky, Buck, Lott & Wanklin 1968; Davies, Quinlan, McKeegney, & Kimbal, 1973; Lloyd et al., 1996) have indicated that psychological adjustment has a powerful influence on the course of medical conditions; poor psychological state has been associated not only with increased morbidity but also with higher rates of mortality.

Some authors, e.g. Eastwood et al. (1985), and Thomas, Hunt, Garry, Hood, Goodwin and Goodwin (1983) did not find a strong relationship between psychiatric disorder and audiological disorder (in these cases hearing loss). There is, however, some evidence to suggest that there is likely to be a high rate of psychological disturbance among patients attending a neuro-otology clinic. Thomas (1984) pointed out that people who have a hearing loss may be psychologically distressed, but there is no one-to-one relationship between the level of hearing loss and the degree of psychological disturbance. Skovronsky, Boleloucky and Bastecky (1981) reported that patients suffering from auditory and vestibular disorders obtain higher mean scores than do control patients on certain items and clusters of the SCL-90 psychiatric symptom inventory, particularly those concerned with anxiety, phobias and depression. In a study of patients attending a tinnitus clinic, 41% of patients expressed psychiatric problems during a structured interview (O'Connor, Hawthorn, Britten & Webber, 1987) and of the total population, 9.5% had moderate to severe psychiatric illness. Psychiatric morbidity was found to be related to previous psychiatric history, unknown aetiology for the tinnitus, and high levels of reported tinnitus annoyance. A quarter of psychiatrically morbid cases was undetected by ENT surgeons.

Similarly, Singerman, Riedner and Folstein (1980) using the General Health Questionnaire (GHQ) (Goldberg, 1978) as a screening device, reported that 20% of patients attending a Hearing Clinic obtained scores indicative of 'definite psychiatric morbidity' with a further 14% designated as 'probably psychiatric'. The extent of the increased risk of psychiatric status appears to be related not only to hearing impairment but also to the presence of associated aural complaints, even in the absence of objective hearing impairment. Berrios, Ryley, Garvey and Moffat (1988) found 29% psychiatric morbidity in a group of patients with inner ear disease, with a higher prevalence of psychiatric morbidity among patients with tinnitus (47%) than among patients in other diagnostic categories (noise injury 35%, Menieres disease

32%, other sensory deafness 25%, and presbyacusis 20%). They found no significant relationship, however, between past psychiatric history and either current diagnosis, current audiometric status, or current psychiatric morbidity. While this study indicates a greater prevalence of psychiatric morbidity among patients with tinnitus, Hallam and Stephens (1985) found higher levels of emotional disturbance among patients complaining of dizziness suggesting that the latter may be a more pernicious symptom.

The present study assesses the prevalence of psychological disturbance among a consecutive series of 120 neuro-otology outpatients. The emphasis in previous studies has been on the administration of questionnaires and inventories that produce a score on the basis of which a subject is classified as either psychiatrically disturbed or not. None of the commonly used instruments have been standardised on neuro-otology patients and the use of these instruments may be questioned in this context. For example, it is possible that the sensory deprivation of hearing loss or the similarities between vertigo and, say, agoraphobia might lead to a greater degree of error than with other populations. The sensitivity (i.e. the extent to which subjects who are psychologically disturbed are identified as such - avoidance of type II errors) and specificity (the extent to which subjects who are not psychologically disturbed are identified as such - avoidance of type I errors) of any instrument therefore needs to be examined with this population. The present study extends the approach of classifying subjects on the basis of response to a questionnaire by incorporating a structured interview, specifically designed for this study and conducted by a clinical psychologist. The interview focused on questions that, on the basis of clinical experience, were considered to be important. It was included to provided a more complete picture of the subjects and therefore allow a more informed judgement of their psychological status than is possible from a questionnaire score.

It was predicted that there would be a higher prevalence of psychological disturbance among neuro-otology patients than among the general population.

Method

Subjects

A consecutive series of 120 patients attending the Neuro-otology Clinic at the Royal National Throat, Nose and Ear Hospital was seen. This clinic receives secondary and tertiary referrals and it is likely that a greater range of etiological factors is encountered than is usual in Neuro-otology practice. Medicolegal cases were excluded from this study because of the greater possibility of additional factors influencing the presentation of their complaints.

Procedure

All patients were given a structured interview designed to elicit information about their auditory complaint, about any behavioural and/or mood disturbance that may be present, and about any association between these factors.

The age and gender of subjects were noted. Subjects were asked what they regarded their main audiological complaint to be. The complaint was categorised in terms of hearing loss, tinnitus, dizziness or 'other symptoms'. Hearing loss and tinnitus were also subdivided into unilateral or bilateral. Symptoms such as pain in the ear or a sensation of fullness in the ears were included in the 'other symptoms' category. Subjects were given the opportunity to report as many symptoms as they wished and the number reported was noted. The duration of subject's symptoms was recorded.

Subjects were asked to describe the effects of their audiological symptoms on their behaviour. Specifically, subjects were asked to describe the impact of their symptoms on their work; on their social life; on their domestic life and their relationships; on their recreation, e.g. ability to watch television, listen to radio, to read for pleasure; on their ability to travel; and on their sleep. Subjects were further asked to say whether their audiological symptoms changed their behaviour in ways such as taking medication; going to bed; taking time off work; or in some other way. Subjects were also asked to describe the effects of their audiological symptoms on their mood. Responses were categorised in terms of none; irritability; depression; and anxiety. Where subjects suggested more than one response they were asked to indicate which was the most relevant and this response was recorded. Subjects were offered the opportunity to provide details of any other way that their symptoms affected them.

In each instance, e.g. effects on work or sleep, the subject's account of the behavioural and mood changes was rated for severity in terms of whether the psychologist judged the effect to be none, mild, or severe. An assessment of the overall level of psychological disturbance was then made on the same three point scale. The psychologist's rating of the behavioural and mood disturbance was then fed-back to the subject. Whenever possible subjects' confirmation of the ratings was sought, however, the final classification was made by the psychologist. Subjects who described minor and/or infrequent changes in behaviour or mood, e.g. slight irritability, occasionally taking medication and carrying on with work as normal, were rated as suffering from mild psychological consequences of their audiological symptoms. Subjects who described more extensive effects, e.g. regularly taking time off work, frequent sleep disturbance, reports of significant mood changes, disrupted relationships were judged to be experiencing serious psychological disturbance. Subjects who were considered to have 'severe' behavioural and/or mood changes were classified as being in need of psychological help.

Subjects were asked whether or not they had received help for psychological problems in the past. Previous psychological help was classified as either none; help from a primary care provider, e.g. the GP; or help from a secondary care source, e.g. a psychologist or a psychiatrist.

The interview was conducted by a clinical psychologist experienced in working with patients with disorders of hearing and balance. The reliability of the conclusions drawn from the structured interview was tested in a sub group of 20 patients. The entire interview was repeated, blind, by a second psychologist, also experienced in the field. The two psychologists agreed closely about the patients' need for help. There was disagreement in only 2 of the 20 patients. These figures yielded a contingency coefficient C value of 0.57 ($X^2 = 9.71$, $p< 0.01$). From this it may be concluded that interview ratings had a satisfactory reliability.

In a further subgroup of forty consecutive patients, the examining physician was asked to rate the patient's overall level of psychological adjustment along a four point scale. The correlation between these ratings and the psychologists rating of overall adjustment was also examined (see below). This was done in order to assess the level of agreement between psychologists and physicians about patients emotional state. Other studies have indicated that emotional distress is often not recognised by medical personnel (Bridges & Goldberg, 1984; Anonymous, 1979).

All patients completed Goldberg's 60-item General Health Questionnaire (Goldberg, 1978). The GHQ was designed to be a self administered screening test aimed at detecting psychiatric disorders among respondents in a community setting, such as primary care or among general medical patients. Goldberg (1978) reported on the factor structure of the GHQ. He suggested that six scales can be reasonably identified. He referred to these as: general illness; somatic symptoms; sleep disturbance, social dysfunction; anxiety and dysphoria; and severe depression. The “general illness” factor accounted for 45.6% of the variance in one analysis and 35% of the variance in a subsequent analysis. Other identified factors such as depression accounted for six per cent of the variance or less. Goldberg (1978) stated that in addition to detecting differentiated psychotic and neurotic syndromes, the GHQ identifies patients who have illnesses that are not readily categorised with the WHO Glossary of diseases. Goldberg (1978) reported on the test-retest reliability of the GHQ in a group of general practice patients. Patients were tested on two occasions six months apart. In subjects whose clinical state was judged, through standardised psychiatric interview, to be similar on the two occasions, the reliability coefficient was r = 0.90. Goldberg (1978) reported the split-half reliability of the GHQ to be 0.95. Goldberg and Blackwell (1970) used a standardised psychiatric research interview in order to validate the GHQ in a group of 200 primary care patients. They reported a correlation of r = 0.80 between the interview conclusions and the GHQ classification. They reported a sensitivity level for the GHQ of 91% and a specificity level of 94.1% in that population. In a study of medical out-patients Goldberg (1972) reported a correlation of r = 0.77 between the GHQ classification of patients and that derived from a standardised interview. He reported a sensitivity level of 80.6% and a specificity level of 93.3% in that population.

The GHQ asks subjects whether they have experienced particular symptoms, "over the past few weeks". Subjects express the extent that they have experienced the symptoms in terms of: "not at all"; "no more than usual"; "rather more than usual"; or "much more than usual". The scoring system adopted was the "GHQ" style, i.e. a symptom that is rated in terms of either of the first two categories receives a score of zero while a symptom that is rated using either of the last two categories receives a score of one. Goldberg (l978) suggested that when using the 60-item GHQ, a score of 11 or 12 should be used as a cut-off point above which scores be considered within a category of significant clinical disturbance. Goldberg (1985), however, points out that the specificity and sensitivity of the instrument will depend upon the particular patient population. For this study, a GHQ score of 11 was used as a cut-off point and the sensitivity and specificity of the scale assessed in relation to the judgements of the clinical psychologist.

Statistical Analyses

Analyses were conducted using SPSS/PC+. The analyses included descriptive statistics, chi-square tests, t-tests for independent samples, and Pearson product moment correlations. Two tailed tests were used throughout.

Results

The mean age of patients was forty-eight years. The mean time since the onset of symptoms was 38 months. There was no significant difference in the age or duration of symptoms between those considered to be in need of psychological help and those who were not. No significant gender differences were found.

Psychological Ratings Of Disturbance

A total of 50 patients (42%) was judged through the interview to be psychologically disturbed, i.e. they had experienced significant behavioural and/or mood disturbances, and they were offered psychological help (Table 1.1).

Symptom			Offered Help	
	n	% of total	n	% of total
Hearing Loss	45	37.5	12	27
Unilateral	18	15.0	5	28
Bilateral	27	22.5	7	26
Tinnitus	44	36.7	20	45
Unilateral	21	17.5	7	33
Bilateral	23	19.2	13	56
Dizziness	22	18.3	14	64
Other (e.g. pain)	9	7.5	4	44
Total	120		50	42

Table 1.1. Number of patients with each main complaint who were offered help following the structured interview.

Many patients had multiple audiological symptoms (e.g. tinnitus and hearing loss). Twenty-seven per cent of those with a main complaint of hearing loss were rated as psychologically disturbed, i.e. they were judged to have severe changes in their behaviour or mood. A similar percentage of those with unilateral loss (28%) and of those with bilateral loss (26%) were rated as disturbed. Forty-five per cent of all patients with tinnitus were considered to be in need of psychological help. Fifty-six per cent of those with bilateral tinnitus were rated as psychologically disturbed compared with thirty-three per cent of those with unilateral tinnitus. Dizziness was associated with greater psychological disturbance: sixty-four per cent of those who complained of dizziness were considered to be disturbed.

Because many patients complained of multiple symptoms, the relationship between number of symptoms and psychological disturbance was examined. No difference was found between the prevalence of psychological disturbance among patients complaining of one symptom and those complaining of two symptoms. However, significantly more of those with three or more symptoms were found to be psychologically disturbed than those with one or two symptoms ($X^2 = 4.3$, $p<0.05$). It was not possible to examine the relationship between particular combinations of symptoms and psychological disturbance because the numbers of subjects falling into each grouping would be too small.

Physicians Ratings Of Disturbance

There was good agreement between the ratings of psychological state made by the examining physicians and by the psychologist. In twenty-nine of the forty patients the ratings were the same. When the rating categories were reduced to two, corresponding to the need for psychological help or not, there was a difference in only five patients. These latter figures yielded a statistically significant contingency coefficient C value of 0.57 ($X^2 = 0.05$, $p < 0.001$). Where there were differences, the physicians rated the patients as more disturbed in four out of the five cases.

GHQ And Decision To Offer Help.

The correspondence between the GHQ scores and the decision, following interview, of whether or not to offer help, can be seen in Table 1.2. From these figures it was found that the GHQ (using a cut-off point of 11) had a specificity rate of eighty-seven per cent (GHQ scores above the cut-off point that corresponded with interview offers of help, i.e. few false negatives) and a sensitivity rate of eighty-two per cent (interview offers of help that corresponded with GHQ scores above the cut-off point, i.e. few false positives).

	GHQ score >11	GHQ score < 10	Total
Help offered	41	9	50
No help offered	6	64	70
Total	47	73	120

Table 1.2. GHQ score and offer of help following interview.

A Chi-square test indicated that there was a significant relationship between GHQ score (high or low) and the psychologist's decision to offer help ($X^2 = 66.0$, $p < 0.001$).

Previous Psychological/Psychiatric Help.

A Chi squared test revealed that there was a significant relationship between level of previous psychological/psychiatric help and the offer of psychological help following the research interview ($X^2 = 12.43$, $p < 0.01$) (Table 1.3).

	Nil	GP	Help from psychiatrist/ psychologist	Total
Help offered	21	13	16	50
No help offered	48	16	6	70
Total	69	29	22	120

Table 1.3. Previous psychiatric history and offer of help.

Discussion

The present results support the view that there is a high prevalence of psychological disturbance among neuro-otology patients. They add to the weight of evidence showing that a high proportion of medical (non-psychiatric) out-patients are psychologically disturbed.

In this sample of neuro-otology outpatients, forty-two per cent were judged to be in need of psychological help for disturbances of mood or behaviour. This judgement corresponded well with a classification based on GHQ score using a cut-off score of eleven. In this study the GHQ was found to have a slightly lower sensitivity than that reported by Goldberg and Blackwell (1970) for primary care patients but in keeping with that reported by Goldberg (1972) for medical out-patients. The specificity of the GHQ in this study was slightly lower than, but close to, that reported by the other authors. The sensitivity and specificity of the GHQ in this study suggests that it is a useful screening device in this setting. The majority of patients offered help accepted it. The highest prevalence of disturbance was among patients complaining of dizziness (64%) followed by tinnitus (45%) and hearing loss (27%). In pointing to a higher level of emotional distress associated with dizziness than with tinnitus, the present data are in keeping with earlier findings from the same clinic (Hallam & Stephens, 1985).

A higher prevalence of emotional distress was found among patients complaining of three or more symptoms. The implications of this finding are not fully clear however it is at least broadly in support of the idea that psychological disturbance is related to general health rather than just to specific symptoms. Previous studies have been divided (O'Connor et al., 1987; Berrios et al., 1988) about whether current psychological disturbance is associated with previous psychiatric history. The present findings support the link between previous and current psychological disturbance. This finding may also be interpreted as pointing to the importance of general well, as opposed to specific symptamology, being important in determining psychological state.

In the current study, unlike others discussed earlier, the physicians tended, if anything, to rate the disturbance as greater than did the clinical psychologist. The good agreement between ratings made by doctors and psychologists in this study may reflect a history of close collaboration over the previous eight years.

As noted earlier, the clinic in which the research took place, i.e. the Neuro-otology Clinic at the RNTNE Hospital, is a secondary or tertiary referral centre accepting patients who have not responded to management elsewhere, or who present diagnostic difficulties. It is possible then that the present sample of patients is not typical of neuro-otological practice. However, in a sample of tinnitus sufferers referred to an ENT surgeon and preselected on the grounds that tinnitus severity was not explained by the presence or severity of organic factors, forty-one per cent were described after interview as psychiatric cases (O'Connor et al., 1987) a proportion very similar to the findings of the present investigation. In the former group, 9.5% had 'severe depressive illness'. It seems reasonable to conclude, therefore, that in those patients with tinnitus who persist in seeking medical help beyond the GP level, forty to forty-five per cent are psychologically disturbed.

Psychological assessment of neuro-otology out-patients contributes in a number of ways to medical management. The assessment clarifies the patient's understanding of and attitudes to the treatment available (e.g. behavioural rather than drug treatment of insomnia). It can also clarify the relative importance of organic and psychological factors in the presentation of illness and the need for psychological intervention where the illness is primarily psychogenic, or where adaptation to chronic symptoms or impairments is the primary goal.

In some cases, the medical complaint may be little more than an indicator of other difficulties of a psychological nature. When these are addressed, the medical complaint may lose any real significance. Hawthorne et al. (1987) reported that psychiatric and psychological treatment of patients with tinnitus using a variety of methods (such as anti-depressant medication, bereavement counselling, marital and family therapy) resulted in a sharp fall in GHQ scores at follow-up assessment although there was little change in the symptom of tinnitus itself. The work of Hallam and Jakes (1985) also suggests that tolerance of tinnitus may develop once psychological problems are dealt with. It has been shown that psychological therapies are beneficial in producing adaptation to tinnitus where the symptom itself remains unchanged (Hallam 1987; Andersson et al., 1995). The methods employed in these studies aim to change the way the patient copes with the symptoms. An evaluation of the full range of benefits (personal, social, economic) of psychological therapy for auditory disorders awaits further research using appropriate comparison groups. While it may be argued that the presence of psychologists or psychiatrists in a medical setting generates a demand for their services, experience suggests that the benefits accruing include a reduction in the number of future medical consultations and in the use of medication and, moreover, in an increase in well-being.

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PART II

The Assessment of Psychological Variables in Cochlear Implant Patients

Chapter 3

INTRODUCTION TO THE CLINICAL PSYCHOLOGY OF COCHLEAR IMPLANTS

The cochlear implant is an electronic device that is intended to provide some degree of acoustical input for people with profound hearing loss. The device receives sound, converts this into an electrical signal that is then carried past the damaged parts of the ear and used to stimulate the preserved parts of the cochlear or the auditory nerve directly. The system consists of a microphone that picks up sound and sends it as an electrical signal to a signal processor where it is modified and then sent to an external transmitter from where it is transferred through or across the skin to a surgically implanted electrode in the ear. Electrical current flows between one or more active electrodes and return electrodes stimulating the auditory nerve to produce a sensation of sound. There are currently a number of different devices in use; they differ in terms of processing schemes (e.g. analogue feature extraction; single or multi channel), number and placement of electrodes, method of transmission and stimulation configuration.

Historical Perspective

The modern history of electrical stimulation of the auditory nerve began with the reports of Djourno and Eyries (1957) in France. The first implantations were carried out by William House in Los Angeles in 1961. Several difficulties were encountered and implantations did not resume until 1969 when three patients received devices, again from House. The project was able to take advantage of progress in other biotechnology fields such as pacemaker research. By the 1970's clinical programmes for cochlear implantation were being developed. The first devices that people could wear were produced and the first long term implantations took place. Opposition to the idea was also emerging in strength. The efficacy of implants was questioned and there were fears that the procedure might be destructive in the long run. The debate was described by Merzenich, Schindler and Sooy (1974). At the time only single channel implants were used.

A study of thirteen cochlear implant subjects was reported by Bilger, Black, Hopkinson, et al. (1977) They reported that implants provided detection of sound over the entire frequency range, that patients could identify environmental sounds, and that lip reading was improved and patients were better able to monitor their own voices. Biliger and Black (1977) however, concluded that "Above all, a single channel auditory input will not provide a speech input that either sounds speech like or is understandable" (p4). This fuelled the assumption that no speech understanding was possible with any single channel device. By the end of the 1970's it was recognised that cochlear implant programmes needed a complete multidiciplinary team, including psychologists to assess suitability of candidates and measure outcome. In spite of this recognition it is still a rarity to find a psychologist as a member of a cochlear implant team.

In the 1980's cochlear implant programmes progressed with considerable pace. Clinical trails began both with adults and, to a lesser extent, with children. In the USA, Food and Drug Administration regulations were applied and commercial manufacturers entered the field. Controversy about the value of the implants continued and was invigorated by the implantation of children. Cochlear implants, however, generally gained a greater acceptance and programmes proceeded with considerable optimism. Schindler and Merzenich (1985) stated "It is clear that the current generation of cochlear implants are of benefit to carefully selected deaf individuals" and Loeb (1985) suggested that cochlear implants had taken the idea of "restoring hearing to patients with hair cell deafness ... from the realm of science fiction to a commercially viable industry" (p17). In November 1984, the USA Food and Drug Administration recognised a cochlear implant system (the 3M Cochlear Implant System/House Design) as safe and effective for profoundly deaf adults. An FDA spokesman commented that it was the first time that a medical device had been approved that partly restored one of the five senses. It was also pointed out by House and Berliner (1986) that "patients who were previously turned away as 'un-treatable' were provided with a new option". While there was agreement that cochlear implants were of value for profoundly deafened people there was less consensus about which was the best device, which patients should be selected, and how to assess the outcome of implantation.

In the 1990s other devices have won FDA approval and several thousand people world-wide have received cochlear implants. Controversy continues but is now largely focused on the implantation of deaf children. There has been a very vocal lobby from within Deaf communities world-wide opposing the use of cochlear implants in children with pre-lingual hearing loss. That lobby continues to question the efficacy of implants and suggests that their use in children is harmful, leading to the creation of 'Frankenstein' type creatures who do not fit easily into either the Deaf or the Hearing world. The more radical lobbyists have suggested that cochlear implants represent a form of genocide on Deaf communities.

Although considerable technical progress has been made in the development of cochlear implants, fundamental questions remain unanswered. There are still enormous individual differences in how much benefit people obtain from cochlear implants (Knutson, Hinrichs, Tyler, Gantz, Schartz & Woodworth, 1991; Lyxell, Andersson, Arlinger et al., 1996) and the discovery of objective predictive variables remains an important quest. There is also less than complete consensus about what outcome measures should be assessed. In the United Kingdom the Medical Research Council's Institute of Hearing Research has conducted a national survey of cochlear implant programmes (Summerfield and Marshall, 1995). One of the findings of that survey was that the recency of onset of profound deafness was the most robust predictor of performance outcome with a cochlear implant. Two other variables that predicted outcome were: good pre-operative lip-reading ability and having benefited in lip-reading from a hearing aid pre-operatively. Together these variables accounted for thirty-three per cent of the variance in a composite measure of ability to recognise speech and environmental sounds.

The Importance of Psychological Assessment

The use of a cochlear implant can be expected to place great demands upon an individual's psychological abilities. In addition, the use of an implant may lead to changes in psychological functioning; it might be expected that the user will perform some tasks more easily and expand his or her repertoire of behaviour. Indeed, if it does not, the value of the procedure can be questioned. The importance of psychological variables in this context has long been recognised (Clark, O'Loughlin, Rickards, Tong,& Williams, 1977; Miller, Duvall, Berliner, Crary, & Wexler, 1978; Crary, Berliner, Wexler & Miller, 1982; Wexler, Berliner, Miller & Crary, 1982) and continues to be advocated by many groups (Chouard, Meyer, Charbolle & Fugain, 1987; Risberg, Aglefors, Bredberg, Lindstrom & Ossian-Cook, 1987; Knutson, 1988). Gantz (1989) has pointed out that candidate rejection from a cochlear implant programme is less often due to medical and surgical considerations than to other factors such as the patient's psychological profile. In addition, Berlin, Jenison, Hood and Lyons (1987) stated that the majority of dropouts from their programme withdrew for reasons other than audiological and medical ones, and they suggested that the emotional and psychological impact of implantation should be given equal weight to the audiological and medical results. It was also reported by Lehnhardt (1989) that patients with better psychosocial status require less postoperative rehabilitation.

Psychological assessment may therefore be regarded as an integral part of the assessment procedure within a cochlear implant programme. This part of the thesis focuses on procedures for the psychological assessment of candidates for, and recipients of, cochlear implants. The work for this thesis was carried out in collaboration with the UCH/RNID cochlear implant programme (London). Procedures used in the UCH/RNID programme, together with some of those from other programmes, that have been outlined in the literature, will be discussed. Historically, much of the effort invested in the psychological assessment of candidates for cochlear implantation, and of implant users, has been in the application of standardised measurement devices such as personality and intelligence tests. The use of these devices will be discussed first. Following this, techniques that allow a more individualistic and possibly more informative assessment will be examined.

Personality Characteristics

It has been suggested by a number of workers that candidates should be assessed using standard personality inventories and be excluded if they have personality characteristics that (1) are 'unsatisfactory' (Clark et al., 1977); (2) would 'make programme completion unlikely' (Miller et al., 1978); or (3) show 'significant signs of psychopathology' (Crary et al., 1982). Crary et al. (1982) consider scores of two standard deviations above the mean on the Minnesota Multiphasic Personality Inventory (MMPI) to be evidence of pathology, although they offer no guidance about whether such a score on a single MMPI scale is sufficient to classify a candidate as pathological or whether high scores on two or more scales are required. As only candidates with normal personality profiles have been included in implant programmes, the question of whether people with deviant personality profiles are, in fact, poor cochlear implant users remains unanswered. It was reported by Crary et al. (1982) that the MMPI scores of 'normal' patients did not predict the number of hours that patients used their implants.

It would certainly seem imprudent to include in a cochlear implant programme someone who shows evidence of personality deviance, however that is defined, where such a programme is in a developmental stage. To do so may be to introduce additional variables that would serve to complicate the evaluation. The use of standardised personality inventories in the assessment of cochlear implant candidates was discussed by McKenna (1986) who suggested that the use of such devices was problematic because of their questionable suitability and utility in this setting. The nature of such inventories is that they are dependent upon normative data. Extremely few such data are available for a deafened population. Knutson (1988) states that the MMPI profiles of cochlear implant candidates seen by his group (Iowa) are on average one standard deviation above the mean in areas of depression, suspiciousness and social introversion. Thus there is a need to establish norms before meaningful decisions can be made using such measurement devices with these samples. Some caution will be needed in this process. Taylor (1970) argued that the content of certain MMPI items is biased against physically disabled people and suggested that, where this is the case, the items should be removed and the scoring of the scales altered accordingly. Thomas (1984) also pointed out that the content of many of the questions in some inventories, including the MMPI, is loaded against the hearing impaired. Such considerations make interpretation, particularly of marginally deviant scores, difficult.

A number of studies have examined changes in personality profiles following cochlear implantation. Miller et al. (1978) examined changes between pre- and post-implant MMPI scores. They found that one year postoperative scores were unchanged from preoperative levels, although most of the patients reported feeling better and made use of the implant. Decreases were, however, noted in depression and suspiciousness as measured by the MMPI in a subsample of patients at 3-5 years' follow-up. A later paper from this group (Crary et al., 1982) reported no changes from preoperative levels in MMPI scores at postoperative assessments. Chute, Parisier and Kramer (1984) reported similar findings.

There are a number of considerations that make the use of standardised personality inventories unlikely to be informative as outcome measures in this setting. These tests seek to assess stable personality traits and thus are unlikely to be sensitive enough to act as short-term measures. Personality changes may be apparent only over a number of years, during which time the person may have been exposed to many diverse influences. Hallam (1976) pointed out that changes in personality test scores are known to be responsive to changes in emotional state. Knutson (1988) argued that any changes in such measures should be lagged against changes in audiological competence. He reported on changes in MMPI scores (and other psychometric measures - see below) as a function of changes in audiological ability; the latter was assessed in terms of percentage correct in a noise/voice discrimination test, and the percentage correct on a sentence test administered in both a sound-only and a sound-plus-vision format. Change on only one scale of the MMPI, suspiciousness, correlated significantly with changes on the sound-only sentence test and the noise/voice discrimination test. It was noted by Knutson (1988) that change on the depression scale did not correlate with changes on the tests of audiological competence, although changes on another measure of depression (that would be expected to be more sensitive - see below) did correlate with changes in audiological competence.

It was pointed out by Crary et al. (1982) that to expect scores that are already within the normal ranges to improve significantly may be unrealistic. It must also be remembered that such tests are more suited to the assessment of large groups rather than the individual. Whilst there may be value in the detection of group changes, or indeed in noting the absence of such changes following implantation, the value of averaged group data, particularly in the selection of the individual candidate, may be very limited (Hersen & Barlow, 1976).

When the UCH/RNID programme was first instigated, the Eysenck Personality Questionnaire (EPQ) (Eysenck & Eysenck, 1975) was used in the assessment of patients. However, the use of the EPQ was discontinued as the scores did not seem to facilitate decision making in the selection of candidates (all candidates scored within the normal ranges) and also there was insufficient variation in scores for it to be a useful outcome measure. Information about the individual's personality and behaviour is obtained instead by interviewing the person and, whenever possible, other significant people in the person's life. Formal tests are resorted to only when such information is inconsistent or unobtainable.

During a symposium on cochlear implantation, Luxford (1984) pointed out that the use of personality measures is no longer part of the routine assessment procedure of the House (San Francisco) group. The New York group (Chute et al., 1984) have also discontinued routine use of the MMPI in the selection of candidates. Again this is, in part, because of the uninformative nature of this assessment approach, but also because their team does not have regular support from a psychologist (Chute, 1995 personal communication). The Iowa group, however, (Knutson, 1988) argued that the abandonment of standardised psychological measures such as the MMPI is premature. Knutson (1988) accepted that successful prediction requires sufficient variance in both predictor and outcome measures. He states, however, that it is apparent from the variance in his own data, and in those reported by others, that in order to identify predictors and document change using such measures more data will be necessary than have been available to date. A larger data set would certainly help to reveal effects that, because of their size, are not apparent from consideration of small groups of subjects. However, variables that are discernible only through use of large data sets may be of limited assistance when making decisions about individuals. The generalisability of findings, presumably a primary reason for using standardised tests, may well be lacking, particularly in the matter of the selection of the next candidate.

Emotional State

Consideration of the candidate's emotional state is likely to yield information that may contribute to the decision-making process. Intuitively, it would seem unwise to select for implantation candidates suffering from psychoses. As Ramsden (1989) pointed out "the last thing that one would wish to do is to put an electrode into the ear of a paranoid schizophrenic". These ideas suppose that the psychological risk/benefit ratio involved in having an implant is unfavourably altered for psychotic patients. Whether or not this is the case is not known. Consideration of psychotic subjects at this stage in the history of cochlear implants would, however, complicate the evaluation process. Psychotic patients are likely to present for cochlear implantation less frequently than candidates suffering from lesser psychological disorders.

The argument that a poor emotional state can affect task performance is made by Lezak (1976). She stated that poor emotional state leads to "such mental efficiency problems as slowing, scrambled or blocked thoughts and words, and memory failure" (p. 111). From a review of the evidence Mathews and Eysenck (1987) also concluded that emotional state can influence cognitive processing. It is conceivable therefore that a state of emotional distress may affect the person's ability to carry out the tasks involved in learning to use an implant. Emotionally distressing states are often assessed using standard questionnaire measures such as the Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock & Erbaugh, 1961) or the General Health Questionnaire (GHQ) (Goldberg, 1978). The GHQ is one of the most frequently used devices for detecting emotional disorders in patients seen in non-psychiatric medical settings. It has also been used in audiological settings (Singerman et al., 1980; O'Connor et al., 1987; Berrios et al., 1988). Study One of this thesis adds to this body of data. However, the question raised above of the applicability of standardised measures in this context is again relevant and, as a minimum, a careful analysis of individual items within such instruments is advisable.

At its inception the UCH/RNID cochlear implant programme assessed emotional state using the Symptom Check List - 90 (SCL-90) (Derogatis, 1977). This was initially administered as part of the routine psychiatric assessment of all candidates. When that routine psychiatric assessment was discontinued the administration of the SCL-90 was continued in an unquestioning way. The SCL-90 and its use in this context are discussed below.

Many people coming forward as candidates for cochlear implantation are likely to be suffering from at least some degree of emotional upset. It was reported in Study One of this thesis that 27% of neuro-otology outpatients who complained of a hearing loss showed evidence of significant psychological disturbance. The prevalence of psychological disorder among the population of people seeking a cochlear implant is not known. There is, however, no reason to suspect that the prevalence would be lower than that reported for hearing impaired subjects in Study One. As cochlear implant candidates are, in effect, prepared to undergo an invasive and somewhat dramatic procedure to relieve their hearing loss it is possible that their discontent with their symptoms is considerable and it may be that the prevalence of emotional disturbance is higher than that reported in Study One. There may be some concern that to exclude people on the basis of emotional disorder would be to exclude so many candidates as to make the programme unworkable. The high prevalence of emotional disorder, however, should not be considered as a reason for excluding it from the selection criteria. It should be noted that emotional states may change; how quickly this happens depends on the reasons for that state. It may be that a candidate whose emotional state excludes him or her from the programme at one time could be considered suitable at a later date. Counselling may contribute to such a change. It may be assumed that a poor emotional state reflects a set of circumstances that are unhappy or worrying for the person. These circumstances merit careful consideration as they may form part of the context within which the cochlear implant is being sought and is to be used (see below).

Measures of emotional distress are likely to be reasonably sensitive and changes are likely to occur more rapidly than changes in personality traits. Emotional state may therefore provide a more appropriate outcome measure than measures of personality characteristics. Knutson (1988) reported that changes on the BDI following cochlear implantation were found to correlate with changes in measures of audiological ability. Miller et al. (1978) also reported that many of their patients stated that they felt emotionally better following cochlear implantation. Similar reports have been obtained from many of the patients implanted by the UCH/RNID team, and at least one patient has reported a reduction in the frequency of episodes of depression following cochlear implantation. Further systematic evaluations in this area may well be fruitful. A note of caution, however, should be struck; some candidates may regard an implant as an alternative to, or preferable to, more conventional psychotherapeutic methods. This is clearly unwise. It is as inappropriate as considering cochlear implantation without due recourse to more established audiological rehabilitation methods.

Intellectual Status

Given that cochlear implant programmes involve educational schemes, i.e. a considerable amount of testing requiring the subject's co-operation, postoperative training and rehabilitation, all of which will place at least some intellectual demands upon the person, it seems reasonable to suppose that the person's intellectual ability should be taken into account. It was suggested by Miller et al. (1978) that on a priori grounds candidates should show no evidence of brain damage or of mental handicap.

A number of authors (Miller et al., 1978; Crary et al., 1982) have considered formal psychometric assessment of candidates' intellectual status to be relevant to the assessment procedure and have reported that all of their patients who had received implants were within normal ranges of intellectual functioning. However, Gantz, Tyler, Knutson, et al. (1988) reported that intellectual assessment measures were not predictive of auditory performance using a multichannel device. Gantz (1989) questioned the use of IQ measures as selection devices, particularly for those who are within normal ranges, and he points to the audiological success of several people with 'modest intellectual ability' and to the limited gains of some with 'excellent intellectual ability'. He suggests that some people with mild learning disability may benefit from 'the additional opportunities afforded by some access to an acoustic environment'.

The usefulness of tests of general intellectual function does seem questionable for the same reasons mentioned in the discussion of personality variables, i.e. they have not been standardised on deafened people, and the provision of implants to only those who obtain 'normal' scores does not test the predictive validity of the measure. In addition, the fact that the most popular intelligence tests, such as the Wechsler Adult Intelligence Scale, are heavily dependent upon verbal administration may disadvantage deafened subjects. At the very least, the testing is likely to be more time consuming than for those with adequate hearing and accordingly more fatiguing. The results are therefore likely to be less valid and reliable. Such considerations will again make interpretation, particularly of marginal scores, difficult. It was suggested by Aplin (1993) however, that the use of standardised tests should not be discontinued in the assessment of cochlear implant patients. She suggests that to do so may result in the loss of a body of data that may be value in longitudinal studies. Nonetheless, she acknowledges the difficulties inherent in the use of such measures in this setting. It is questionable to what extent very long term changes in such measures may be attributable to the use of a cochlear implant. As with personality measures (discussed above) there may be other influences on a person's performance on tests of intelligence over the long term. This may be particularly important if the argument for the inclusion of such tests is to demonstrate whether or not the long term use of cochlear implants leads to cognitive decline.

Tests that are not dependent upon verbal administration, such as the Raven Progressive Matrices, may avoid some of the difficulties mentioned. A significant positive correlation between Raven Progressive Matrices scores and changes in acoustic competence as measured by a noise/voice discrimination test was reported by Knutson (1988). In a later paper from the same group, however, Gantz et al. (1988) reported that the Raven Progressive Matrices were not predictive of ability to use an implant to process sound.

A number of researchers (Miller et al., 1978; Crary et al., 1982 and Chute et al., 1984) reported no significant changes in intellectual status at post-implant assessments. This is perhaps not surprising because, like personality tests, most tests of general intellectual function are robust instruments sensitive only to larger changes. Again any expectation of an improvement in scores already within normal ranges may be unrealistic. Crary et al. (1982) pointed out that there is no evidence of cognitive deterioration resulting from prolonged use of an implant. The House Group no longer routinely use IQ tests (Luxford, 1984); Chute et al. (1984) reported that the New York group have also discontinued the use of such tests for the same reasons mentioned with regard to personality tests.

Within the UCH/RNID programme, some attention is given to the matter of intelligence. Less reliance, however, is placed on psychometric testing than on indicators such as educational and occupational achievement and the person's general level of functioning within his or her environment. When an appeal to psychometric testing is necessary because of incomplete or inconsistent information from other sources, then non-verbal tests such as the Raven Progressive Matrices are used. Those who have received cochlear implants within the UCH/RNID programme have all been of at least average intellectual ability. To date, no candidate has been rejected on the basis of low intellectual ability. There is no evidence to suggest that any changes in intellectual ability have taken place post-operatively.

Knutson (1988) reported that laboratory tests of information processing, including a vigilance task requiring subjects to identify changes in patterns, and a symbol cancellation task, correlated with ability on the noise/voice discrimination test. It was subsequently reported by Knutson et al. (1991a) that experimental cognitive measures that assess the ability to rapidly detect and respond to features imbedded in sequentially arrayed information accounted for up to 30% of the variance in implant outcome. Lyxell et al. (1996) reported that the performance of cochlear implant candidates on tests of verbal cognitive abilities predicted their speech understanding six to eight months after implantation. The cognitive tests used assessed internal speech (a rhyme judgement test), speed of verbal information processing (e.g. name matching, lexical decision making) and of short term or working memory (a reading span test and a word span test). The application of such tests of more specific cognitive function seem to be more fruitful in identifying predictor variables than would the use of more general tests of intellectual ability and there is a need for further research in this area. It also seems likely that the use of such tests will prove to be more informative than the traditional appeal to the length of time since profound hearing loss.

The Functional Context/The Patient's Expectations

The use of a cochlear implant may be regarded as a behaviour subject to the same laws as any other behaviour. In order for behaviour to occur and to be maintained, it is necessary for that behaviour to be reinforced. Reinforcement is any event that makes the recurrence of the behaviour more likely. In essence, behaviour will be reinforced, and therefore will be likely to continue, if it serves some useful function for the individual. Behaviour that is not reinforced or that is punished will stop. The reinforcement may be an overt gratification or it may be more subtle. What constitutes reinforcement of a useful function will vary with each individual. Owens and Ashcroft (1982) gave an account of functional analysis in applied psychology. When considering whether or not a candidate is suitable for cochlear implantation, information should be gathered about whether the candidate's use of the implant is likely to be reinforcing for him or her. The consequences that the candidate expects from his or her use of the device need to be considered and judged against the collected wisdom about what changes are possible and likely.

The issue is not simply confined to what the candidate expects the quality and level of the new acoustic input to be. In addition, an assessment is needed of what the candidate expects to be different about his or her life after cochlear implantation. Most candidates hope for improvements in their lives. Whether the candidate's use of the implant and the new acoustic input that this will bring will lead to the expected improvements is the point at issue. The changes in lifestyle hoped for by some candidates seem less likely to be fulfilled than those of others. For example, a candidate seen within the UCH/RNID programme hoped for an improvement in her poor relationship with her husband. Careful interviewing of the couple revealed, however, that the discord between them lay primarily in matters unconnected with her hearing loss and that the discord had in fact predated the hearing loss. To expect a cochlear implant to resolve problems unconnected with the person's hearing loss would seem over ambitious and unlikely to be fulfilled. This candidate was considered unsuitable for this and other reasons. She went on to apply to other implant programmes. Another candidate applied for a cochlear implant in the expectation of a reduction in her sense of isolation and her level of stress. She had little contact with the world outside her family and also described herself as cut off from her family and unable to respond to their demands. It transpired that the family did not have good communication skills, e.g. they did not face her when speaking to her. Without a change in the family's behaviour, it would seem unlikely that her use of an implant would be fruitful. The provision of basic communication skills training was a more appropriate direction to follow. Further, part of her motivation in seeking an implant was to please her family. To undergo such a procedure primarily for the benefit of others distances the possible sources of reinforcement, making them less accessible and less predictable, and may raise difficult ethical issues. This is a consideration that has been raised with a number of candidates. Such a situation would be clearly untenable when the aspirations of others are in conflict with those of the candidate. The latter circumstance has been encountered locally only once. A candidate's answer, however, to the question "Who suggested that you ask for a cochlear implant and why?" may produce useful information.

One candidate (who will be referred to here as P1) was in the process of divorce when he asked to be considered for an implant. His legal advisers had told him that his hearing impairment made it unlikely that he would win custody of his children and therefore of the family home. He believed that if he were to obtain an implant this would influence the divorce court in his favour. This belief constituted his primary motivation for undergoing the procedure. It seemed very questionable whether an implant would decisively influence a court. This man was suffering from a mild depressive episode as a result of the marital dispute. Therefore the functional context within which he was seeking an implant was at best unstable, but more probably unlikely to be such as to sustain his use of the device. He was, however, considered suitable in all other respects and did receive an implant. Postoperative assessment at 1 year revealed that he had not achieved his ambitions in the divorce court; the implant was frequently broken and he described it as of little value to him when it was working and he did not often use it. A separate assessment, using a Repertory Grid technique, confirmed that he perceived the implant as having made no difference to his life (see below).

Another candidate (P2) who was considered suitable from all points of view for cochlear implantation, and who received an implant, went on to find little use for the device and rarely wore it. The main reason for this was a change in his circumstances. Some months after the operation he lost his job. The job loss meant that he had little opportunity to communicate with others; improved communication had been his main focus when seeking the implant. His use of the device therefore was not reinforced. The change in circumstances was not foreseen. A Repertory Grid assessment was also carried out with this patient (see below).

The case examples of P1 and P2 highlight the importance of the functional context within which the implant is to be used. If the use of a cochlear implant does not serve the function that was expected of it, not only is its use likely to stop but also it may have a negative emotional impact on the person. Unfulfilled expectations can constitute a loss that may, in turn, render the person vulnerable to emotional problems, such as depression. Candidates who are already emotionally distressed may be particularly susceptible to this.

Within the UCH/RNID selection procedure, considerable emphasis is placed upon the assessment of the likely functional value of an implant for each candidate. Information is gathered from interviews about the handicaps that the candidate is experiencing, both as a result of his or her hearing loss and for any other reason, and about the changes that the candidate envisages. A structured interview is used to review these factors for each major area of the patient's life, e.g. home, work, social life etc.

Candidates are considered suitable when it is thought likely that there is an opportunity for an implant to serve a useful function, i.e. when there appears to be a high probability that the act of using the device will he reinforcing.

Postoperative Interview Data

On the basis of interview data, Miller et al. (1978) reported that post-operatively most patients felt better and made routine use of their cochlear implant. They suggested that after an initial 'high' during which new sounds were tested, a period of disillusionment follows which may last for up to a year, after which patients become more realistic about the device and go on to develop skills in its use. Patients reported feeling less cut off from their environment and more able to take part in social events because of improved speech reading, better voice monitoring and more awareness of when others are speaking.

In addition to the psychometric assessments mentioned above, Crary et al. (1982) gathered information from clinical interviews with patients. Consistent with the findings of Miller et al. (1978), they found that patients reported an initial sense of disappointment (each hoping to have become a star patient) followed by an acceptance of the limitations of the device and a regaining of enthusiasm. On the basis of the clinical interviews, they went on to suggest that cochlear implants help to reduce patients' sense of isolation, restore their confidence about interpersonal functioning, improve their speech reading and make them aware of valuable warning sounds.

Patients within the UCH/RNID programme are interviewed post-operatively at regular intervals. The rationale and structure behind such interviews are those outlined above in the discussion of the functional context within which the implant is to be used. An assessment is made of the value that the implant has given and of the associated behavioural and other resulting changes. As in the assessment of candidates, each major area of the patient's life - family, social life, employment situation etc. is reviewed and an assessment is made of any behavioural and other changes. Reference is made to the expectations that the patient expressed during initial candidacy interviews and a review is conducted of the extent to which these have been fulfilled. A number of changes are commonly reported. Most patients report a greater awareness of environmental sounds and this appears to be intrinsically pleasurable for many patients, although a very small number are disappointed at the quality of the sound. This greater awareness leads to certain changes in behaviour, e.g. the patient answers the door rather than someone else, or the patient is free to carry on with other activities while waiting for the kettle to boil or for the washing machine to finish. Many patients report a reduction in the sense of isolation, and some also report a heightened sense of safety when out of their homes; in some patients this is matched by a greater preparedness to go out alone. Improvements in communication are reported by many, although not by all patients using the UCH/RNID device. Many patients report an increase in the quantity of communication, with fewer reporting an improvement in quality; indeed it has been noted that a small number of patients complain of an initial reduction in their ability to understand what is being said to them because the new auditory input from the cochlear implant distracts them from their speech reading; this difficulty eases with time and practice.

The interview data suggest that improvements in communication are most consistently noticed in the home, probably due to the greater familiarity with the people involved and the opportunity to communicate. Patients report spending more time in conversation with their families and taking a more active part in conversations. This seems to he facilitated by gains in temporal perception of sounds, which allows a greater awareness of gaps in the conversation, and by improvements in voice level control. Some patients report a change in the mode of communication used, with a reduction in writing and a corresponding increase in spoken communication. Whilst such changes are generally unequivocally welcomed, in at least one patient it was likely that they contributed towards marital breakdown; improved communication permitted discussion of painful marital disputes previously left dormant because of perceived communication difficulties. It is helpful if the cochlear implant team is aware of such difficulties so that they can proceed with appropriate sensitivity and provide support.

Improvements have also been reported in the sphere of patients' social lives. There is, however, a greater range in the extent of such improvements. Whilst some patients have reported very small changes in their social lives, e.g. exchanging greetings with a neighbour, others have told of increases in the number of parties given and attended and a resumption of attendance at church services and theatre performances. Again such patients have reported a greater preparedness to take a more active role, e.g. speaking directly to strangers rather than allowing their partners to interpret during social events or when simply out shopping.

A smaller number of patients have reported benefits from using their cochlear implants while at work, e.g. more fluent one-to-one communication with colleagues, and a slight improvement in ability to follow proceedings during business meetings. To date, no more specific employment advantages have been reported. At least one patient, however, expects promotion; this expectation appears to stem as much from the employer's review of policy regarding the employment of hearing-impaired people, as from a greater ability to perform the job because of increased auditory input. A number of patients have reported being unable to use their implants at work because of ambient noise levels. These patients have tended to be in 'blue collar' jobs.

In addition to the reduced sense of isolation and increased sense of safety mentioned above, patients commonly report improvements in their sense of confidence. This sense of improved confidence is reported in varying degrees by most patients and across many areas of life. Such improvements may be considered natural consequences of increased activity and are likely to help sustain such increases.

Some of the changes noted may be due to factors other than the additional acoustic input provided by the cochlear implant. Many patients report changes in the behaviour of others towards them; in particular patients state that there is an increase in others' expectations of them. From interview accounts it is clear that the novelty of the operation leads to others expressing a greater interest in patients and having more interaction with them. One patient reported that he became a local celebrity following the operation, with people in his community involving him, for the first time, in social activities and even stopping him in the street, talking to him and wishing him well. Such changes inevitably broaden patients' experience and lead to an increase in their sphere of activity that can be maintained by naturally occurring positive consequences. One patient has had a clear broadening and increase in his activity level in spite of having repeated and long lasting malfunction of his device. Clearly some account needs to be taken of such non-specific effects; these may be difficult to discover and measure other than through interview. Unfortunately, it is not uncommon for others to believe initially that cochlear implant patients have had their hearing totally restored; realisation that this is not the case can lead to some loss of interest on the part of others.

Other Questionnaire Measures of Change

It has been suggested by Wexler et al. (1982) that the ultimate arbiter of the value of any medical advance is the consumer. They suggested that, in striving for objective measures of the efficacy of procedures, phenomenological evidence is often ignored. They take the position that, since recipients of treatment are concerned with the improvement that the treatment brings about in their lives, their perceptions about such changes should be included in the data used to evaluate the procedure. Accordingly, Wexler et al. (1982) used pre- and post-implant questionnaire measures to assess the impact of cochlear implants on both patients and their relatives. The questionnaires were compiled from data obtained from extensive interviews with patients and focused on eight main themes: sense of safety, emotional reactions, nature of interpersonal relationships, social activities, sense of isolation, communication problems, employment, and involvement with hobbies and recreational activities. They reported that, post-operatively, the greatest improvement was seen in answer to questions concerned with feelings of isolation, issues of safety, comfort at social events, difficulty in communication and participation in solitary activities such as going to shops or restaurants alone. They reported less benefit in the areas of employment and involvement with hobbies and recreational activities. No change was reported in the number and quality of patients' friendships. Relatives perceived improvements in the patients' emotional reactions, level of frustration in communication, the quality of the patients' voice and their concern about the patients' safety. Relatives also noted that there was an increase in the number of social events they attended with the patients. Wexler et al. (1982) point out that their patients did have implants at the time of the assessment and therefore the information obtained was necessarily retrospective.

East and Cooper (1986) devised a questionnaire to assess the subjective benefits and problems encountered at one year post-implantation by patients in the UCH/RNID programme. They reported that an awareness of environmental sounds and improved speech modulation were the most significant subjective benefits. Improvements in speech reading ability were less marked.

The employment implications of having a cochlear implant have been reported on by Dinner, Ackley, Lubinski, Balkany, Reeder and Genert (1989). Using a self-report questionnaire they surveyed people in the USA who had received any one of the four major designs of cochlear implant. They noted improvements in quantity and quality of spoken communication at work and significant changes in the major communication modes used at work; lip-reading remained the most commonly used mode of communication, but hearing through the implant replaced writing as the second most frequently cited mode. Job satisfaction was improved for the majority of their target population. Few of their subjects reported a change in income or job promotion as a result of their use of their implant; however, over half of their subjects reported an increase in overall job performance. It should be noted, however, that the conclusions of Dinner et al. (1989) refer only to that subgroup of their originally larger sample who used their implant while at work. Many of their subjects were in employment but did not use their implants while at work. It is possible that those subjects did not use the device at work because they did not find it beneficial in that setting, in which case the conclusions may be slightly over-optimistic. The majority of their subjects who were employed were in 'white collar' jobs, were college educated, had stable job histories and had lost their hearing post-vocationally.

Summary

In summary, much of the effort to date in the psychological assessment of cochlear implant candidates and patients has focused on the evaluation of people on standard measures of personality and intellectual function. Such evaluations have been valuable in establishing that prolonged stimulation through the use of a cochlear implant does not lead to deleterious changes in intellectual function or personality (Crary et al., 1982). As predictors of implant use, they are largely untested but seem to add little to the decision making process in the selection of candidates and are unlikely to be sensitive as outcome measures.

One of the single most important factors in the assessment of a candidate is a determination of the likely value of an implant in terms of the reinforcements that its use will bring to the patient. If the use of an implant cannot or does not effect changes in lifestyle that the candidate seeks or comes to regard as valuable, then the use of the implant will stop. This is a crucial issue because many candidates seek changes that are unlikely to be fulfilled. This matter is most usefully assessed through face-to-face discussion with the candidate and, if possible, with relatives. Post-operatively, the discussion can review the circumstances in which the implant is used and the accompanying changes in behaviour. Interview data collected by the UCH/RNID group and others (Miller et al., 1978; Crary et al., 1982) point to improvements in the lives of most implant recipients. Interview data are clearly important, permitting relevant assessments of each individual and allowing documentation of events that more quantitative measures might overlook. Interviews have, however, the disadvantage of being anecdotal; and are clearly not the most systematic method of data collection. While questionnaire measures developed by individual groups (Wexler et al., 1982; East & Cooper, 1986; Dinner et al., 1989) tend to confirm the interview findings concerning outcome, there remains a need for an evaluation of outcome of cochlear implantation that avoids the difficulties surrounding standardised tests and that is not anecdotal.

Chapter 4

STUDY TWO

REPERTORY GRID TECHNIQUE IN THE ASSESSMENT OF COCHLEAR IMPLANT PATIENTS.

Introduction

The Repertory Grid technique stems from Personal Construct Theory, a framework for understanding and assessing personality, developed by Kelly (1955). Kelly proposed that people, in going about their everyday life, act as a scientist does. Just as a scientist develops concepts to interpret and predict events, so 'man as scientist' develops constructs through which he understands the world. Kelly proposed that people perceive similarities and differences amongst others and amongst events and that they use constructs to impose order on these phenomena. Each individual develops a unique set of constructs or ideas that he or she uses to understand and structure his or her own environment. It is not necessary to accept whole-heartedly Kelly's position in order to make use of the Repertory Grid technique. Even without a strong commitment to Kelly's theory, the technique can be fruitful. The Repertory Grid technique traditionally involves eliciting from people what constructs they are employing in order to structure their environment. The technique therefore allows the individual to state what variables are important and which are to be assessed. The technique provides a numerical statement of an individual's perception of him- or herself at the present time vis-a-vis other people, and of him- or herself at different points in time. The use of the Repertory Grid technique provides a method for describing a person's perceptions of the impact of a cochlear implant upon him- or herself. It avoids difficulties such as the lack of appropriate normative data and the inclusion of irrelevant measures that surround standardised instruments, such as questionnaire measures of psychological status. It also has the advantage of providing an assessment that is suitable for mathematical manipulation.

This study describes the use of a Repertory Grid technique, employing the method of elicited constructs, to assess a series of cochlear-implant users.

Method

Subjects

The subjects were 10 patients from the UCH/RNID cochlear implant programme in London who had been using a single-channel cochlear implant for between 1 and 5 years. The subjects represent a consecutive series of patients who had returned to the clinic for regular post implantation reviews and were unselected in any other way. The ten subjects represented all of the patients available at the time, i.e. all that had at least one years experience of using an implant.

Procedure

There are a variety of forms that the Repertory Grid technique can take; these are described by Fransella and Bannister (1977). In this study a traditional triadic card sorting technique was used. This involved asking the subjects to consider a list of people who were significant to them. This list included the subject at different points in time, including the past, present and future and an 'ideal self'. The people in the list were referred to as 'elements'. A list of the core elements used is given in Table 2.1. Other elements were included, as necessary, in order to broaden and balance the assessment. Two subjects were also asked to consider 'me if I lost my implant' as an element. Each subject was presented with three of the elements at a time, e.g. 'me now', 'me prior to implant' and 'my spouse', and asked to state any way in which any two of them were alike and different from the third. For example, the answer may have been that the first and third elements were 'confident with people' whilst the second was 'not confident'. The idea that people may vary in their confidence with other people was then considered to form one dimension in that subject's construction of the world, i.e. it formed one of that subject's constructs. The procedure was repeated until a list of at least 10 constructs had been elicited for each subject.

Me prior to hearing loss
My spouse
Me before cochlear implant
My best friend
Me now
A hearing impaired person I admire
A hearing impaired person I dislike
A normally hearing person I admire
A normally hearing person I dislike
My 'ideal self'
Me in one year from now

Table 2.1. Core elements used in the Repertory Grid assessment.

Constructs are bipolar in nature, e.g. happy/sad, independent of/reliant upon others. The bipolar constructs and elements for each subject were arranged in a matrix, with the elements arranged across the top. One pole of each construct, e.g. happy, independent, formed the left side of the matrix; the opposite pole, e.g. sad, reliant upon others, formed the right side of the matrix. The subjects were then asked to rate each element against each construct. For example, they were asked whether they considered the element 'me prior to hearing loss' as primarily happy or sad. Refinements of that judgement were then made using a seven-point numerical scale. The extent to which the first or right pole of the construct (happy) applied to the element was stated, by the subject, using the numbers one, two or three. Number one was used to indicate that the element was very well endowed with that aspect of the construct, e.g. 'me before hearing loss' was very happy. If the opposite pole of the construct was judged to be more applicable then the numbers five, six and seven were used. Seven was used to indicate the extreme, e.g. 'me before cochlear implant' was very unhappy. Number four was used when a construct was considered not relevant to a particular element, e.g. if the subject did not have tinnitus prior to the onset of hearing loss then number four would be used to rate the element 'me before hearing loss' on a construct concerned with how distressing tinnitus might be.

Analysis

The grids were analysed using the method of principal components analysis (Slater, 1977) on a computer package called Flexigrid (Tschudi, F. Flexigrid 5.0, unpublished computer manual for the Flexigrid program). Preliminary analysis of the data showed that a two-factor solution explained 60-90% of the variance in the data for all grids. In addition, inspection of the construct distribution on the third factor on those grids where a lower proportion of the variance in the data was accounted for by a two-factor solution showed the factor to have little apparent psychological meaning. For this reason two main orthogonal factors were used as axes describing factor space. The relative positions of the elements were plotted within that factor space. Additionally, in each case, the distances of the elements 'me before hearing loss', 'me before cochlear implant' and 'me now' from the element 'my ideal self' were calculated. The element 'ideal self' was taken as an origin and the distances of other elements were calculated with reference to that point. In two cases, a plot of the first two principal components was also inspected and compared with an independently gathered account of the patient's pre- and postoperative progress.

Results

The inter-element distances between 'ideal self' and 'me before hearing loss', 'me before cochlear implantation' and 'me now' are shown in Table 2.2 for all 10 subjects.

	Me prior to Hearing loss	Me prior to cochlear implant	Me Now
SI	1.00	1.60	0.76
S2	0.67	1.71	1.04
S3	1.33	1.10	0.99
S4	0.64	1.17	0.50
S5	0.51	1.12	0.80
S6	0.80	1.64	1.02
S7	0.49	1.48	0.50
S8	0.40	1.34	1.47
S9	1.20	1.11	0.39
S10	1.11	1.64	1.25

Table 2.2. Inter-element distances for cochlear-implant users ('ideal self' = 0.00).

Eight of the ten subjects experienced a substantial move away from the ideal state during the period between losing their hearing and receiving a cochlear implant (S3 and S9 did not). Nine of the ten subjects experienced a substantial move in the direction of the 'ideal self' after receiving an implant (S8 did not).

The mean values, for the subjects as a group, of element distances from 'ideal self' (including confidence limits) are shown in Figure 2.1. A clear general pattern of worsening after hearing loss and then improvement after cochlear implantation can be seen.

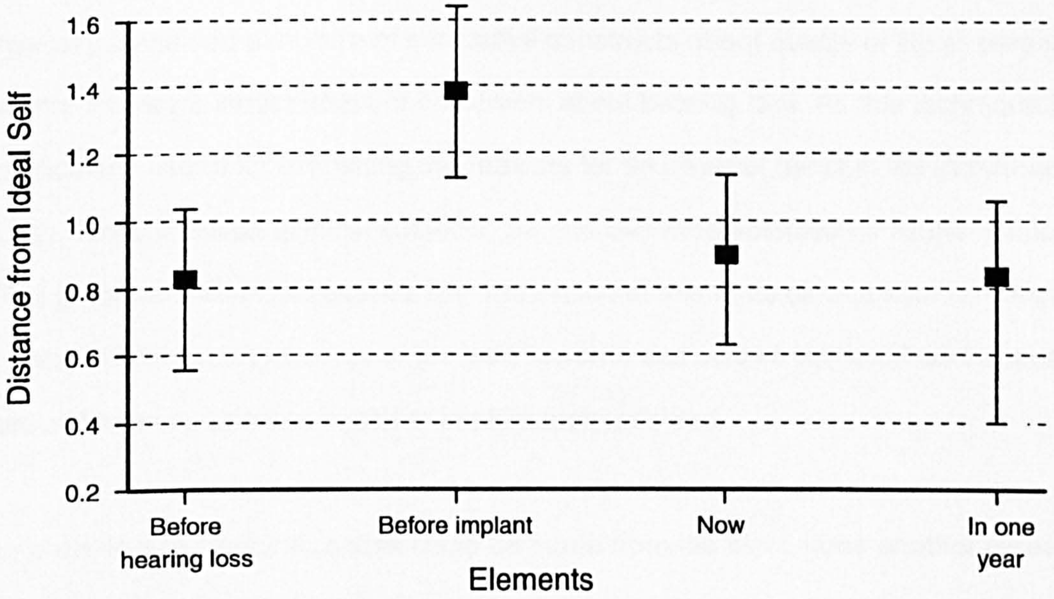

Figure 2.1 Distance of Elements from Ideal Self (including confidence limits)

Three subjects showed responses that differed from the main group. Two subjects (S3 and S9) reported a progressive movement towards the 'ideal self' independently of their hearing loss or attempts to alleviate it. One subject (S8) reported a move away from the 'ideal self' following hearing loss that continued in spite of cochlear implantation. Both of those who filled in the element 'me if I lost my implant' felt this would represent a distinct movement away from 'ideal self'. For the group of subjects overall, the difference between the values for 'before cochlear implant' and 'now' is significant ($t = 2.77$; < 0.01) showing that the use of a cochlear implant improved subjects' psychological well-being.

Inspection of the plots of elements and constructs on the first two components often gives further information about the subjects' experience of their implant and about their attitude towards their hearing disability. In general, all the grids were similar in their factor space. The chief constructs defining the first principal component in every grid were those that related to hearing loss and the disabilities in social living that arise from it. The second principal component was more variable in its composition but typically contained a mixture of evaluative constructs about quality of life or personal worth, that were independent of constructs about hearing loss. As this technique is particularly useful for examining the reasons for an unusual result in the individual case, two somewhat atypical subjects (S8 and S9) were selected for further inspection. The grids were atypical because the distribution of elements did not show the expected relation between movements of the 'self' towards and away from 'ideal' as the events around hearing loss and cochlear implantation unfolded.

In order to see what inferences could be made from the plots alone another researcher (CD) who was blind to other information was asked to comment on the grids. In each case this comment was compared with the independent judgement of the principal researcher (LMcK) given prior to seeing the grid result.

S8 (Figure 2.2) reported only consistent worsening in his condition and no improvement since cochlear implant use. The plot in this case is extremely tight with a first component that is of considerable importance. The element "ideal self" is closest to "me before hearing loss" and loads strongly on both first and second principal components, i.e. 'quiet and modest' and 'happy, confident and relaxed'. After hearing loss and before cochlear implantation there is a dramatic move towards the negative end of the first component, accounting for a greatly increased distance from 'ideal self'. The main change is an increase in feeling 'tense, ill and discontented' as opposed to a 'happy life'. Thus the impression generated is that loss of hearing has had a dramatic impact on this subject. He rates his current situation as little better. One suspects that he feels that only complete restoration of his hearing would be sufficient to help him. CD commented that he might also be clinically depressed.

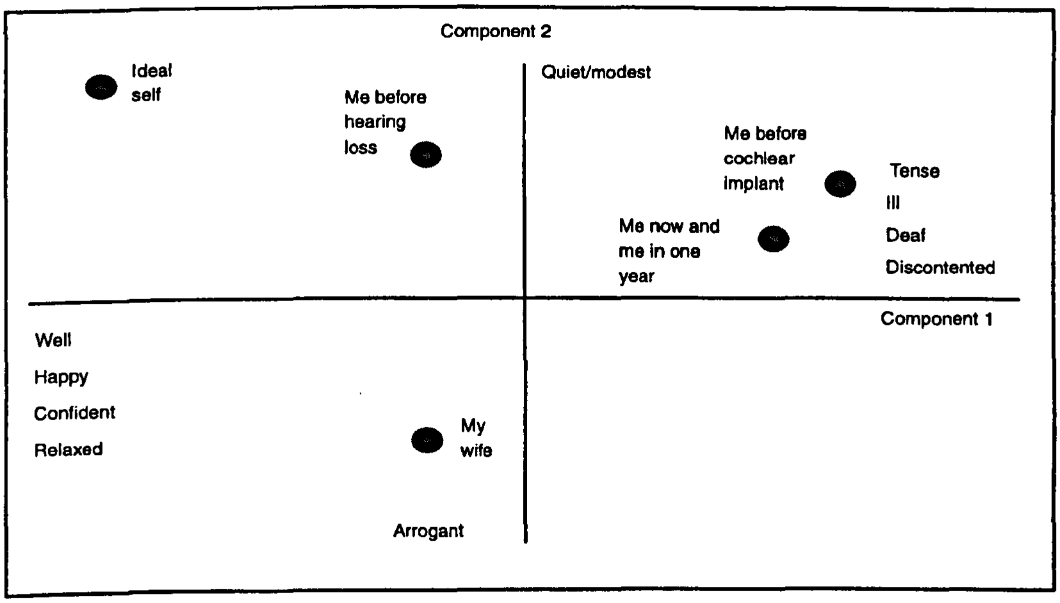

Figure 2.2 Plot of factor space for S8

This analysis closely parallels the conclusions drawn from LMcK's review with S8. It was noted in that interview that S8 had found little use for the implant and regarded the auditory input he received from it as irritating.

S9 (Figure 2.3) reported a consistent movement towards 'ideal self' throughout his life. Inspection of his plot reveals a first component that is principally to do with hearing and communication skills and a second component that is concerned with stable versus changing relationships, single versus married, happiness and quality of life. His hearing loss and then his subsequent cochlear implant result in large movement on the first component, but through all of this his self-image moves consistently on the second component towards increased stability, good quality of life, maturity and becoming established in a job.

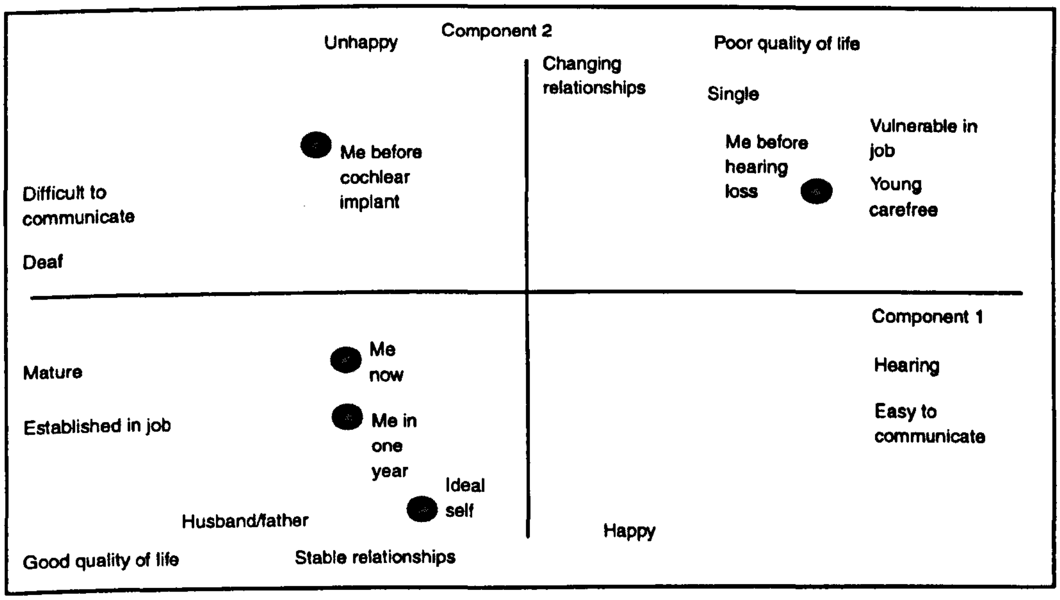

Figure 2.3 Plot of factor space for S9

CD's impression was that this grid reflects a person whose hearing loss has been a major element in his life but who feels that, nonetheless, he has matured, got married and made a life for himself both at home and at work. It is this movement that accounts for the consistent improvement in his image.

At post implant assessment LMcK noted that S9 had received considerable benefit from his implant. It was also observed, however, that since the operation he had got married, and this was thought to be an important and positive change for him. He did not believe that his use of his implant had contributed significantly to his relationship with his wife. It was noted that he had been quite young when he lost his hearing and had matured considerably since then. The changes in him were judged to be reflections of this maturation process, which had been assisted, to some extent, by the implant.

Discussion

The results of the Repertory Grid analysis indicate that for most people the use of a cochlear implant leads to perceived improvements in psychological well-being. The results show that subjects can perceive themselves as being significantly closer to their 'ideal self' after surgery than before it.

The size of the perceived improvements was surprisingly large. Many subjects rated themselves as having returned to a situation almost as close to their 'ideal self' as they remember being in before they lost their hearing. This might seem incongruous given the modest extent of the acoustical benefit that might be expected from a single channel implant. The reasons and processes generating the large changes that were observed must remain speculative at this stage. It may be that hearing impaired people who make a satisfactory adjustment to their condition do so, in part, by modifying their image of their 'ideal self'; they may change their life aims, playing on their strengths and diminishing the relative importance of their weakness. This study did not attempt to measure changes in the concept of 'ideal self' over time and subjects probably rated that element as current 'ideal self'. It was also noted that many subjects rated 'self before hearing loss' very close to 'ideal self'.

Knutson et al. (1991) also reported significant changes on standardised psychological measures following use of multichannel implants; these changes were largely unrelated to changes in measures of audiological ability. As in the present study not all of the subjects studied by Knutson et al. (1991) reported psychological benefit. In seeking to explain large psychological changes following cochlear implantation one must reject a simple threshold effect such as that implied by Ramsdell (1962) in which any audiological improvement would lead to psychological benefit. A more complex threshold model that takes into account patients' expectations and changes in other life events would appear to be more appropriate from the present findings. There was a further parallel between the Knutson et al. (1991) findings in that not all of their subjects had met their expectations and some did experience other life changes that influenced their psychological well-being. The results of three subjects from the present study differed markedly from the main body of results. These 'unusual' results appear to be explained in terms of inappropriate expectations on the patients' part and life changes independent of cochlear implant use.

The technique of Repertory Grid elicitation is time-consuming and the concepts are not quickly grasped by all patients. It commonly took between one and one and a half hours to explain the technique to a patient and to elicit the constructs. Following this, patients took from fifteen to thirty minutes to complete the grids. Furthermore, this study used the technique to provide only a retrospective report. The Repertory Grid technique, however, has a number of strengths that make it particularly useful in this setting. It produces a measure that often has good face validity and that has the benefit of being cast in the patient's own terms. Another strength of the technique is the way that it allows for the inspection of individual differences. The two anomalous cases described illustrate that an inspection of the plots of elements and constructs can reveal individual reasons for the observed results. In both cases, the reasons suggested by grid inspection closely agreed with the information gathered in clinical interview. Thus the use of grid analysis may help in disentangling the effects of the implant from those provoked by general changes in life and circumstances.

It is also possible to speculate on the use of the Repertory Grid technique in making predictions about the suitability of candidates for cochlear implantation. For example, if those patients who show greatest benefit from the use of an implant are those who are coping well preoperatively, this might be reflected in a personality structure that has high coping skills, realistic aims and a world view that would not be totally taken over by hearing loss. In such circumstances the cochlear implant would be less likely to be associated with unrealistically high expectations and be more likely to be seen as a tool to be used for improving life. In contrast to this, it might be expected that those candidates who go on to do less well with an implant would be those who show grids with a rigid system of constructs, centred on hearing and hearing disability. In these, the first principal component may be entirely taken over by constructs that link hearing to good quality of life and that account for a very high percentage of the variance. The postoperative grid of S8 showed many of these features. This is, however, an area for further development and research.

The finding from this study were published as: McKenna, L. & Denman, C. (1993) Repertory grid technique in the assessment of cochlear implant patients. Journal of Audiological Medicine, **2**, 75-84.

Chapter 5

STUDY THREE

PSYCHOLOGICAL ASSESSMENT OF COCHLEAR IMPLANT CANDIDATES WITH NON-ORGANIC HEARING LOSS

Introduction

The arguments about the applicability of standardised questionnaire measures in the assessment of cochlear implant patients have already been outlined. The present study seeks to contribute to the debate by examining the use of one standardised questionnaire, the Symptom Check List 90 (SCL-90), a questionnaire measure of psychiatric state developed by Derogatis (1977), in two groups of implant candidates; a group with a non-organic element to their hearing loss and a control group of subjects randomly selected from the other implant candidates. The SCL-90 was an established part of the assessment procedure in the University College Hospital/Middlesex Hospital (UCH) cochlear implant programme, London.

The UCH cochlear implant programme has assessed over 600 patients since 1982; a total of 120 has progressed to implantation. During this period five patients with a non-organic component to their hearing loss have been identified by the implant assessment team. In each case the non-organic element had not been detected by the referring audiological department. The audiological profiles of these patients have been described by Spraggs, Burton & Graham (1994). Clearly, the implications of operating on and implanting a device in people with non-organic hearing loss (NOHL) are profound. It is to the advantage of the assessment team to be able to identify patients presenting in this manner by as many means as possible.

In the early years of the programme all candidates were assessed by a psychiatrist as well as by a clinical psychologist. As mentioned earlier in this thesis, the psychiatric screening included assessment by SCL-90. The practice of having all candidates assessed by a psychiatrist was discontinued but the administration of the SCL-90 to all candidates continued as a matter of routine. This study assess the value of the SCL-90 in the assessment of the NOHL candidates in particular, and discusses the implications of this device in the assessment of implant patients in general. The study compares the SCL-90 profiles of the five candidates with NOHL with those of five other routine candidates. It was predicted that the NOHL group would have more abnormal SCL-90 profiles than the control group.

Method

Subjects

Two groups of subjects were studied. The index group consisted of the four women and one man who presented as candidates for cochlear implantation for whose audiometric studies revealed a non-organic component to their hearing loss. These subjects will be referred to here as S1-S5. An underlying hearing loss was noted in four of these five subjects. Two had a unilateral dead ear. For comparison a second group of five implant candidates was studied. These were randomly selected from the pool of other candidates who had gone on to receive an implant, here referred to as C1-C5.

Procedure

Subjects completed the Symptom Check List -90 (SCL-90) a ninety item, self report measure, of psychological status. The SCL-90 is designed to reflect the psychological symptom patterns of psychiatric and medical patients. Derogatis (1977) describes the SCL-90 as a measure of "current, point-in-time psychological symptom status" (p. 5). He stated that it is not a measure of personality. Derogatis (1977) suggests that the SCL-90 may be used appropriately with any individuals falling with the psychiatric or medical patients categories, except acutely psychotic patients or patients who are "delirious, retarded, or severely debilitated" (p. 6). He points out that the questionnaire has been used successfully in order to differentiate those with psychiatric disorder, in a broad range of populations including alcoholics, drug abusers, student counselling clients, cancer patients, neurology patients and patients with cardio-vascular disorders.

Each item on the inventory is rated by the patient on a five point scale of distress (0 - 4) ranging from "not at all" at one pole to "extremely" at the other. Subjects are asked to rate their experience of each of the ninety items over the preceding seven days. Derogatis (1977) argues that this time frame provides the most relevant information about a subject's current psychological status.

The SCL-90 provides a psychological profile in terms of nine primary symptom dimensions: somatisation, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation and psychoticism. The somatisation dimension reflects distress arising from perceptions of bodily dysfunction; complaints focused on symptoms with a strong autonomic mediation. The obsessive-compulsive dimension reflects symptoms that are highly identified with the standard clinical syndrome of the same name. The interpersonal sensitivity dimension focuses on feelings of personal inadequacy and inferiority in comparison with others. The symptoms of the depression dimension reflect a range of the manifestations of clinical depression including symptoms of dysphoric mood, withdrawal, lack of motivation, and suicidal ideation. The anxiety dimension is composed of symptoms that are associated clinically with high levels of anxiety including nervousness, tension and panic attacks and feelings of apprehension and dread. The hostility dimension reflects thoughts, feelings and actions that are characteristic of the state of anger, including aggression, irritability, rage and anger. The items in the phobic anxiety dimension focus on the disruptive manifestations of phobic behaviour and closely reflect agoraphobia in particular. The characteristics of the paranoid dimension represent this behaviour as a disorder of thinking. The psychoticism dimension includes items indicative of a withdrawn, isolated schizoid life style and first rank symptoms of schizophrenia. The SCL-90 includes seven items that are not subsumed under any of the primary symptom dimensions but which are thought to be clinically important and contribute to the global scores that may be derived from the questionnaire.

The SCL-90 also provides three global indices of distress: the Global Severity Index (GSI) the Positive Symptom Distress Index (PSDI) and the Positive Symptom Total (PST). The global indices of distress each allow an expression of the overall extent of psychopathology. The GSI combines information on numbers of symptoms and intensity of distress. Derogatis (1977) suggested that the GSI represents the best single indicator of the current level of disorder. The PSDI is a measure of the intensity of the subject's perceived distress. It functions as a measure of response style in that it indicates whether the subject is augmenting or attenuating symptomatic distress. The PST represents the number of symptoms that the subject reports as experiencing to any extent.

Formal normative data are available from populations of heterogeneous psychiatric patients, non-patient normals and adolescent psychiatric out-patients. Derogatis (1977) also gave details of data from several other clinical samples including, cardiac patients, weight reduction patients, alcoholics, cancer patients, pain patients and patients with sexual dysfunctions or adjustment problems.

Derogatis (1977) reported test-retest reliabilities for each of the nine dimensions. The values range from $r = 0.80$ for anxiety to $r = 0.90$ for phobic anxiety and refer to a population of psychiatric out-patients with a test-retest interval of one week. He also reports on the internal consistency of the dimensions. Data from "symptomatic volunteers" revealed coefficient alpha values ranging from 0.77 for psychotocism to 0.90 for depression. Derogatis (1977) reported invariance coefficients for the nine dimensions across the parameter of gender; these range from 0.51 for paranoia to 0.85 for hostility.

In a study of concurrent validity, Derogatis, Rickels & Rock (1976) compared SCL-90 dimension scores with scores from the MMPI. Each dimension score had its highest correlation with a like construct, except in the case of the obsessive-compulsive dimension for which there is no directly comparable MMPI scale. Boleloucky and Horvath (1974) examined the correlations between the SCL-90 dimensions and those of the Middlesex Hospital Questionnaire (MHQ) in a group of subjects with a variety of psychological disorders. Correlations ranged from r = 0.36 for phobic anxiety to r = 0.74 for anxiety/free floating anxiety. The correlation between the SCL-90 GSI and the MHQ Global score was 0.92. A number of researchers have reported on the discriminative validity of the SCL-90. For example, Weissman, Slobetz, Prusoff, Mezritz and Howard (1976) reported that the SCL-90 discriminated clinically depressed from non-depressed patients in a methadone maintenance programme.

In the present study the SCL-90 was scored according to the Derogatis (1977) instructions. Raw scores on each primary symptom dimension were compared with the normative data that are available for a non-psychiatric population. This allowed the raw scores to be converted into standardised T-scores that were then plotted on psychological profile sheets (the raw score equivalents are printed on the summary sheets every 0.5 standard deviations for all dimensions and indices; T-scores and percentiles are indicated on the sheets - see Figures 3.1 & 3.2).

The data were also viewed in terms of the mean raw score across all nine primary symptom dimensions; this represents an alternative summary of the extent of psychopathology commonly used in clinical settings (Barker, 1995 personal communication). A mean raw score of more than 1.00 may be used to classify an individual as suffering from significant psychological problems.

Results

The profile of one subject (S1) with a non-organic component to the hearing loss indicates high scores (i.e. more than a standard deviation above the mean) on six of the nine primary symptom dimensions. The scores on the remaining dimensions were within normal limits. This subject's scores on all three global indices were also high, indicating a significant overall degree of psychopathology (Figure 3.1). This subject's mean raw score was 1.42, again indicating significant psychopathology (Table 3.1).

S1	1.42	C1	0.46
S2	0.09	C2	0.84
S3	0.09	C3	0.66
S4	0.12	C4	0.89
S5	0.06	C5	0.61

Table 3.1. Mean Raw Scores on SCL-90.

One other subject (S2) from the non-organic hearing loss group obtained one score that was more than one standard deviation above the population mean (Figure 3.1). All of the other scores obtained by this subject, and by the remaining three subjects in this group (S3, S4 & S5), were either within normal limits or below the lower ranges of the scale (Figure 3.1; p77). All of these subjects obtained low mean raw scores (Table 3.1).

All subjects within the comparison group (C1-C5) obtained scores of more than one standard deviation above the population mean on some of the primary symptom dimensions. Many of these subjects' scores on the global indices were also elevated

(Figure 3.2; p78). However, none of their PSDI scores were more than one standard deviation above the population mean and none obtained a mean raw score of over 1:00 (Table 3.1).

Four of the NOHL group (S1-S4) obtained their highest score on the Somatisation dimension. The subject S5 obtained her second highest score on this dimension. The Somtisation scores of S1 and S3 were over one standard deviation above the mean. The Somatisation scores of the remaining NOHL subjects were within one standard deviation of the mean.

SCL-90 SYMPTOM PROFILES

SUBJECT GROUP

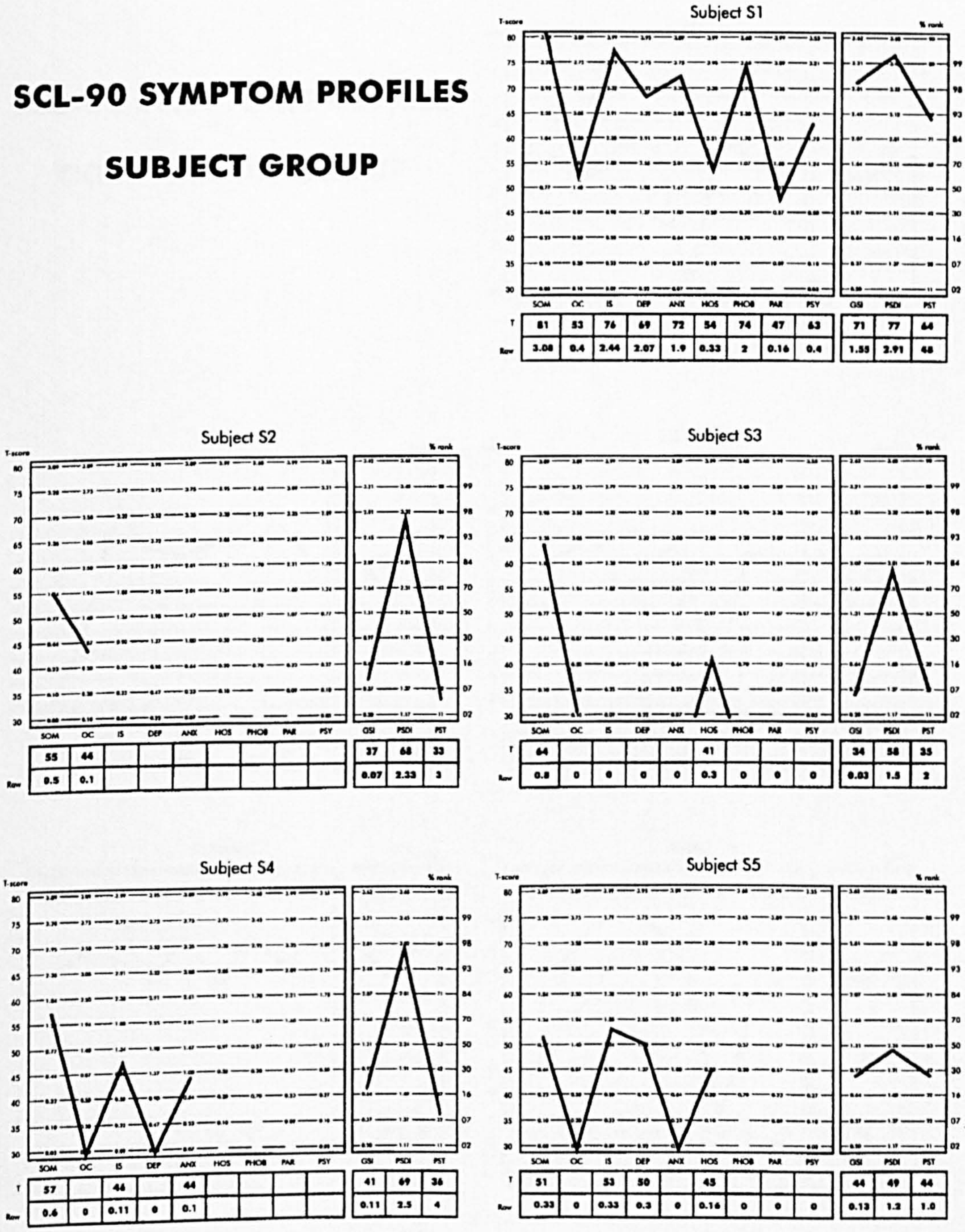

Figure 3.1 SCL-90 Profiles for S1 to S5

SCL-90 SYMPTOM PROFILES

COMPARISON GROUP

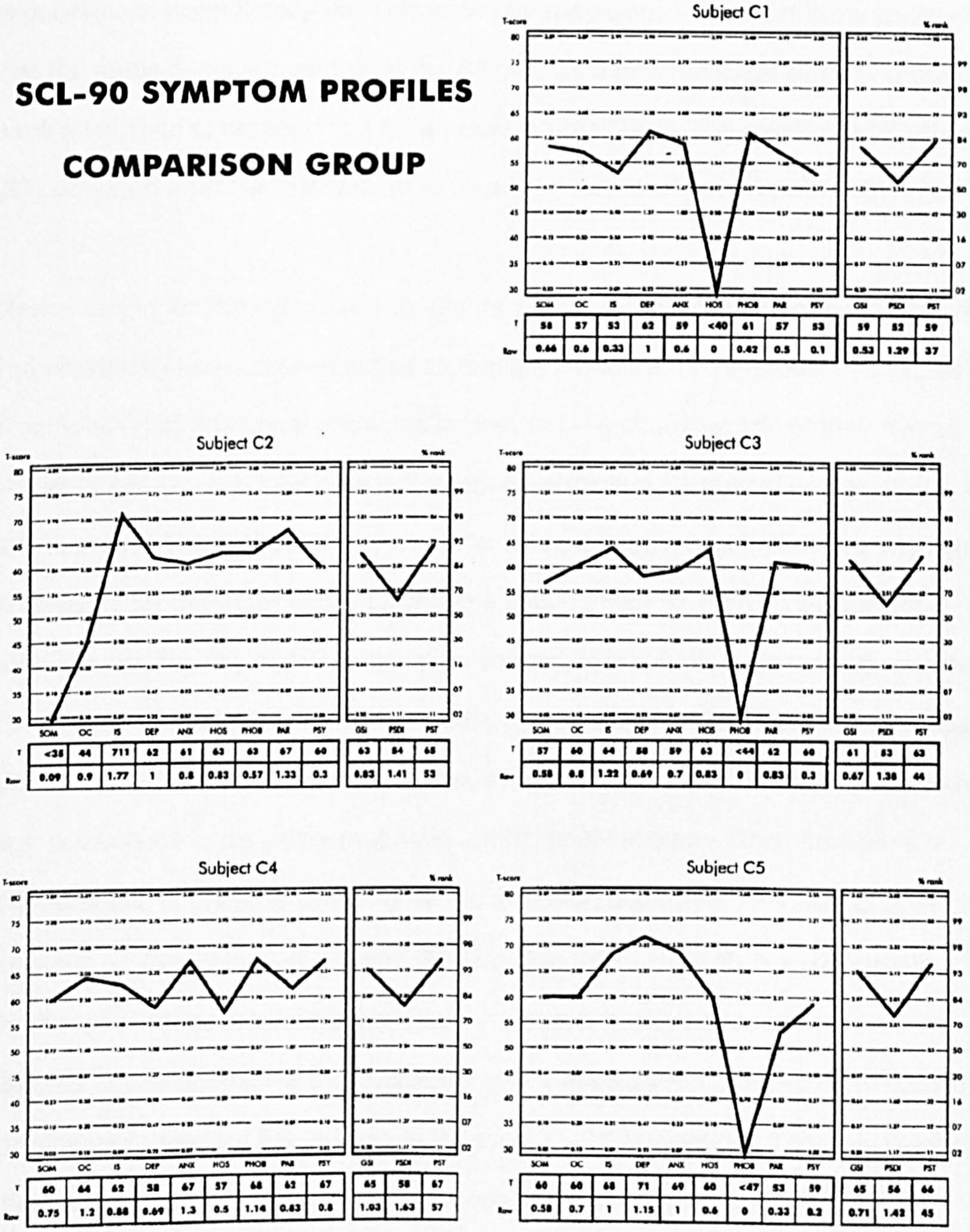

Figure 3.2 SCL-90 Profiles for C1 to C5

Discussion

The most notable feature in four of the five NOHL subjects was the presence of very low scores on most of the primary symptom dimensions of the SCL-90. These subjects appear to be dissimulating. They are presenting with fewer problems than many people experience in normal daily life. This is clearly suspicious. The most likely conclusion is that the subjects have recognised the SCL-90 as a psychological screening device and have attempted to respond to it in "an extra normal" way. The remaining NOHL subject (S1) obtained a profile that was more clearly indicative of psychopathology.

Dissimulation or "faking good" represents a difficulty with the use of such instruments that previously has not been anticipated in the literature. In the present NOHL cases, dissimulation of emotional problems is likely to be a characteristic of their overall presentation. Of particular note is the representation of Somatisation symptoms in the NOHL group. The highest score of four of these subjects was on this primary symptom dimension; for the other subject it was the second highest score. Two subjects obtained significantly high Somatisation scores. This symptom dimension reflects distress attributed to perceptions of bodily dysfunction. The symptoms are focused on autonomic nervous system arousal. The symptoms have been demonstrated to have a high prevalence in disorders that have a functional aetiology. Somatisation is a characteristic of patients suffering from conversion disorders. This aspect of the NOHL subjects' profiles is in keeping with the idea that these subjects are representing emotional conflicts in terms of physical symptoms. It may be, however, that the demand characteristics of the cochlear implant assessment process lead many other candidates to present themselves in as good a light as possible. This is in keeping with observations made by McKenna (unpublished data) from the use of the Beck Depression Inventory with fifty cochlear implant candidates; less than ten per cent of candidates obtained BDI scores that would classify them as even "mildly depressed". This is a lower prevalence of emotional disturbance than the results of Study One of this thesis would suggest. The difference may be due to the fact that the BDI assesses only one aspect of emotional disturbance, i.e. depression, however, this aspect is likely to be a particularly relevant one in any group of subjects who have experienced a loss of one kind or another. The findings of the present study, taken together with these other observations, suggest that the results of questionnaires in this context need to be regarded with caution and should be considered in the light of all other available information about the individual candidates.

Although the SCL-90 has acceptable psychometric properties its unquestioned use would have technically mis-classified four of the five NOHL subjects. Fortunately, the psychological profile that emerged from these four NOHL candidates was clearly unusual, so much so that the mis-classification is patently obvious. An uncritical use of the SCL-90 (and similar devices) may lead to a greater number of mistakes being made than if the results of the questionnaire were ignored. In assessing the value of a test in the decision making process reference needs to be made to the frequency, or base rate, of the problem in the population concerned (Anastasi, 1972). Extreme base rates permit little improvement in prediction by means of a test. For example, the use of a test with a specificity rate of 75% (i.e. it correctly classifies 75% of subjects) in the assessment of a condition that is prevalent in 20% of the population can lead to a 25% error rate. If the test results were ignored and all subjects classified in one direction the error rate would be only 20%. The use of the test has reduced the accuracy of classification. This effect will increase as the prevalence of a condition approaches the extremes. Under such circumstances the costs (including of patient's and professional's time) of administering a test may outweigh any benefit that it offers. The improvement in prediction is greatest when base rates are closest to fifty per cent. While a literature search has failed to reveal a statistic for the prevalence of NOHL, clinical experience suggests that it is a relatively rare condition. Assuming that all those who have presented to the UCH programme with NOHL have been detected then the base rate in this population is 0.8%. In seeking to detect this problem in this population the conclusion that the SCL-90 or other questionnaire measures of emotional state must be regarded alongside other data is again highlighted.

Four of the NOHL cases did not reach the stage of formal assessment with the psychologist. As yet we need to find out more about the particular psychological stresses that lay behind these five cases. Unfortunately, two of the subjects did not respond to attempts to contact them and the remaining three cases (including the one that had been seen by a psychologist) refused further contact.

Although the SCL-90 proved useful in the detection of the NOHL cases it did so in an unexpected way. The present findings illustrate the previously unexpected problem of dissimulation in the use of psychometric instruments. The use of psychometric devices appears to have a limited role to play in the assessment of cochlear implant candidates; they may offer little useful information about most individual patients. They may be helpful, however, in identifying unusual cases.

PART III

TINNITUS AND COGNITIVE FUNCTIONING

Chapter 6

INTRODUCTION TO TINNITUS AND COGNITIVE FUNCTIONING

Tinnitus is the perception of noise in the absence of any external stimulation to produce that noise. It is not a disease but a symptom that can be produced by an enormous variety of changes in the auditory pathway. It is also associated with a range of complaints, one of which is impaired cognitive functioning. It is with this aspect of tinnitus complaint that this part of the thesis is concerned.

Tinnitus is almost always a phantom auditory perception, perceived only by the patient. It cannot be measured objectively. Until the early 1980's there seemed to be a tacit assumption that complaint about tinnitus was uni-dimensional. Since then it has become clear that complaint about tinnitus is multifaceted. One aspect of tinnitus complaint focuses on difficulties in cognitive functioning. Most of the work that has gone in to the assessment of tinnitus has been concerned with the development of verbal interviews or other self report systems and with psychoacoustical estimations of tinnitus parameters, e.g. tinnitus matching and masking measures. To date this research effort has paid little attention to complaints about cognitive dysfunction, and no systematic studies of the problem have been carried out. The prevalence of tinnitus in the population, and the extent of complaints about cognitive difficulties in the tinnitus population, make this an important issue. An understanding of the nature of the cognitive dysfunction may also help to further the understanding of tinnitus and its mechanisms.

The prevalence of tinnitus.

The prevalence of tinnitus has already been alluded to. To elaborate on this reference will be made to the United Kingdom population. The National Study of Hearing (NHS) conducted by the Institute of Hearing Research (Davis, 1989) revealed that 10% of the adult population experienced prolonged spontaneous tinnitus. Tinnitus caused severe annoyance in 1% of the population and brought about a severely reduced ability to live a normal life in 0.5%. A larger proportion (34%) of the population experience tinnitus to a lesser degree, e.g. only after loud noises or for less than five minutes at a time. In a Swedish study carried out by Axelsson and Ringdahl (1989) it was found that 14.2% of the population suffered from tinnitus and that it was a severe problem for 2.4%. Coles (1984) found that there was an increase in the prevalence of tinnitus with age and Sataloff, Sataloff and Lueneburg (1987) found a 24% prevalence rate of tinnitus among healthy elderly people.

Children also experience tinnitus. Nodar (1971) reported that 15% of a sample of 2000 children aged 11 to 18 years reported tinnitus and Graham (1981) found that 64% of children attending Partially Hearing Units experienced tinnitus. In a later study, Graham (1987) found that tinnitus was reported by 29% of profoundly hearing impaired children. This thesis is concerned only with adults with tinnitus. The high prevalence of tinnitus in the population means that any difficulty associated with the symptom is of considerable importance.

The Effects of Tinnitus.

The complexity of tinnitus complaint has received greater attention in recent years. Tyler and Baker's (1983) study was amongst the first in the modern era to articulate the idea that tinnitus complaint is multidimensional. Using an open-ended questionnaire they asked members of a tinnitus self-help group to list all of the difficulties caused by their tinnitus. They found that tinnitus was associated with a diversity of problems. Sleep disturbance was the most commonly reported difficulty. Emotional problems such as depression, anxiety and insecurity were also frequently mentioned. Tyler and Baker (1983) divided tinnitus complaints into four categories: effects on hearing, on life style, on general health and on emotional problems. More recently, Stephens, Lewis and Sanchez (1993) used the same open-ended questionnaire in the assessment of 436 patients attending the Welsh Hearing Institute in Cardiff. They found that people with tinnitus most commonly recorded its effects in terms of despair or frustration, depression, upset or stress, irritation, inability to relax and problems with concentration.

Jakes et al. (1985) asked patients who presented at a neuro-otology clinic complaining of tinnitus to complete a questionnaire concerning features of tinnitus and other symptoms. Patients also rated various aspects of complaints about tinnitus and its effects on 19 scales that were part of routine clinical assessment. Audiometric measures of tinnitus intensity, including loudness matching and masking levels, were also collected. Factor analysis identified two general tinnitus complaint factors, 'intrusiveness of tinnitus' and 'distress due to tinnitus'. The self reported loudness of the tinnitus was distracting, unpleasant and resulted in an inability to cope. The distress factor was heavily loaded on by items measuring the effect of tinnitus on mood, family and social life and work. Three other tinnitus complaint factors of a more specific nature were also identified. These related to 'sleep disturbance', 'medication use' and 'interference with passive auditory entertainment' such as listening to music or watching television. Other neuro-otology symptoms and the audiometric measures did not load on these factors. While self reported loudness was the major item in the intrusiveness factor, audiometric measures of tinnitus loudness were unrelated to other dimensions of complaints.

Jakes et al. (1985) reported that more people indicated that they objected to the persistence of the tinnitus than to the loudness of it and suggested that patients' descriptions of their noises as persistent may be interpreted as the noises being uncontrollable or having strong emotive significance.

Hallam et al. (1988) devised a questionnaire measure of tinnitus complaint (the Tinnitus Effects Questionnaire (TEQ)). This consisted of forty statements describing the most common effects of tinnitus, as judged by the authors' clinical experience. Subjects drawn from an outpatient neuro-otology clinic rated these statements using a four point scale. A factor analysis of the data revealed three factors: emotional distress, auditory perceptual difficulties and sleep disturbance. Following this factor analysis a second, improved, questionnaire was designed and factor analysed. This second factor analysis revealed essentially the same three factors. 'Sleep disturbance' was expressed as difficulties in getting to sleep, waking in the night and early waking. Difficulties in ignoring the noises and in being able to relax were also associated with sleep disturbance. The item 'I have always been a light sleeper' did not load on the sleep disturbance factor. This implies that insomnia was tinnitus related. The 'emotional distress' factor was made up of items reflecting loudness and unplesantness of the noises, worries about the persistence of the noises and emotional effects such as irritability, anger and sadness. The 'auditory perceptual difficulty' factor was made up of items reflecting difficulties in following conversations and items reflecting distortion of sound and difficulty in locating sounds. These findings broadly replicated the earlier work by these authors (Jakes et al., 1985) although the 'intrusiveness' factor found in the earlier study was not identified in its original form.

Hiller and Goebel (1992) sought to replicate the factor structure reported by Hallam et al. (1988) using a German translation of the TEQ. They studied a population of chronic tinnitus patients undergoing an inpatient treatment programme. Factor analysis of their TEQ revealed a total of thirteen factors, although it was possible to give a meaningful interpretation to only five: cognitive and emotional distress, intrusiveness, auditory perceptual difficulties, sleep disturbance and somatic complaints. Hiller and Goebel's (1992) study also revealed an intrusiveness factor. This feature of tinnitus complaint was apparent in the earlier work by Jakes et al. (1985). Intrusiveness was characterised by the unpleasantness and loudness of the noises and by inability to ignore them and to concentrate on other activities. In the Hallam et al. (1988) study these characteristics were associated with emotional distress and sleep disturbance. The German findings were therefore, in large measure, similar to those of Hallam et al. (1988).

Hiller and Goebel (1992) pointed out that 68% of the total variance was accounted for by the thirteen factors revealed by their factor analysis and that the first four factors accounted for 44.2 % of the variance. They suggested that there is therefore a degree of unexplained variance within the TEQ. The first six factors identified by Hallam et al. (1988) in their TEQ accounted for 80% of the variance within that questionnaire; however only three of these factors were easily interpretable. Wilson (1991) developed an Australian tinnitus reaction questionnaire with four factors accounting for 66.4% of the variance of that instrument. It may be that there are areas of tinnitus complaint that are under represented in these measures.

In a clinical setting tinnitus patients' complaints of anxiety, depression, irritability, sleep disturbance and difficulties in hearing are all commonly recognised. Problems with concentration and memory are also among the most frequently mentioned of difficulties. Problems in cognitive functioning may be one area of complaint that is not well represented by the various tinnitus complaint questionnaires. The Tinnitus Effects Questionnaire of Hallam et al. (1988) contains one question relating to concentration.

Cognitive difficulties associated with tinnitus.

Problems with concentration and confusion were mentioned by one third of the Tyler and Baker (1983) sample, and Stephens, et al. (1993) found that 22% of their sample reported problems with concentration. A number of patients did not mention concentration problems on the questionnaire but did so in a subsequent interview. This increased the figure complaining of concentration difficulties to 26.6%. Vernon (personal communication 1992) found that 38% of his sample of tinnitus patients reported such problems "often" while a further 34% reported them "sometimes". Andersson (personal communication, 1996) found that seventy percent of a group of 177 tinnitus patients reported concentration problems during a structured interview.

In a clinical setting most tinnitus patients find it difficult to define the cognitive difficulties that they experience. They complain of a variety of difficulties including finding it difficult to follow what people are saying and difficulty in reading and carrying out paper-work related tasks and other tasks that would traditionally involve short term memory.

It has generally been assumed that any disruption of concentration that tinnitus causes is due to the emotional distress associated with the symptom. Hallam et al. (1984) and Hallam (1987) suggested that tinnitus noises are troublesome because they receive attention. The more meaningful the noises become the more attention they receive. It was suggested that the act of attending to intrusive tinnitus interferes with other functions such as mental concentration and sleep. Hallam (1987) also suggested that it is likely that sensory factors (e.g. the intensity of the noise) are important in determining intrusiveness.

Hallberg and Erlandson (1993) explored the characteristics of people who complained about their tinnitus and of those who did not complain. Amongst other things, complainers scored significantly higher on self reported concentration difficulties. For both complainers and non complainers subjects with more complex tinnitus involving combined sounds scored significantly higher on reported concentration difficulties. Erlandsson, Rubinstein, Axelsson and Carlsson (1991) reported that depressed patients also scored significantly higher on self report measures of irritability and concentration. While these studies suggest that emotional factors may influence subjects' reports of concentration difficulties they also raise the possibility that cognitive difficulties may be related to the tinnitus per se.

That emotional state can disrupt cognitive functioning has long been recognised. It has been suggested that emotion interrupts information processing by diverting cognitive effort to emotionally significant stimuli (Mathews & McLeod, 1985). The assumption that concentration difficulties are an aspect of the emotional distress associated with tinnitus however requires careful consideration. The relevant questions load on different factors in the different questionnaires. Concentration problems load on the "emotional distress" factor of the original TEQ and on the "sleep disturbance" factor on the refined version (Hallam et al., 1988). Concentration problems formed part of the "intrusiveness" factor in the German questionnaire (Hiller & Goebel, 1992) while complaints of distraction loaded on a "cognitive and emotional distress factor". Concentration difficulties loaded on "interference" and "severity" factors on the Australian questionnaire (Wilson, 1991). This inconsistency suggests that cognitive problems may not be only a reflection of emotional distress and that the complaint is not fully accounted for by the different questionnaires.

Central factors in tinnitus perception.

Historically, research has focused on a search for a tinnitus generator; the assumption has been that the most likely site for a generator is in the cochlear. A focus on peripheral mechanisms, however, may be unhelpful in explaining how individuals with identical audiometric profiles report different levels of severity and distress. It is also important to note that surgical sectioning of the auditory nerve often fails to abolish tinnitus (House and Brackman, 1981; Ronis, 1981).

In more recent years, an increasing emphasis has been placed on central factors in the tinnitus process. Evidence for the importance of central factors comes from different sources. Charles (1977) reported that ECT provoked tinnitus. Salah, DeQuardo, Jibson, Carli and Tandon (1995) presented a case study of a patient suffering from depression, the primary cause of which was judged to be tinnitus. In this case ECT reduced the intensity of the tinnitus. These studies, while providing only indirect evidence, at least point out that brain insults can alter the experience of tinnitus.

More direct evidence for central involvement in tinnitus was sought by Hoke, Feldmann, Pantev, Lutkenhoner and Lehnertz (1989) who reported significant differences between the wave forms of the auditory evoked magnetic field (AEF) of tinnitus sufferers and normally hearing subjects. They suggested that their results pointed to a uniformed central manifestation of tinnitus independent of the origin of the tinnitus. In an attempt to replicate these findings, Kristeva, Leutkenhoener, Ross, et al. (1992, unpublished) reported differences between the wave forms of the AEF of tinnitus sufferers and control subjects which were described in terms of a "strong trend" but were not statistically significant.

Colding-Jorgensen, Lauritzen, Johnson, Mikelsen & Saermark (1992) also failed to find differences in auditory evoked cortical magnetic fields (AEF) in similar populations. Colding-Jorgensen et al. (1992) compared the amplitude and latency of the N100 and P200 waves in tinnitus patients and normal subjects but found no differences. Event related potentials (ERP) reflect brain activity associated with specific perceptual and cognitive processes. Attias, Urbach, Gold and Sheemesh (1993) argued that if cognitive or perceptual processes have an effect on, or contribute to, the subjective sensations of tinnitus then this may be apparent in changes in the auditory event related potentials (ERPS) of tinnitus patients. They examined twelve patients with noise induced hearing loss (NIHL) and tinnitus and a control group of twelve subjects without tinnitus but matched for age and hearing loss. They found no differences in auditory nerve or brain stem functioning between the two groups but did observe differences in central processes; using the N1 and P2 and P3 as dependent measures they reported lower amplitudes in these measures in response to auditory stimuli. The N1 and P2 components are thought to reflect early and rapid detection of the physical attributes of the stimulus; P3 is regarded as a measure of the psychological processes of recognition and classification. Attias et al. (1993) point out that multiple auditory cortical regions in the superior temporal lobe have been proposed as the origin of the auditory N1 and P2 components. P3 is thought to come from the limbic system and associated areas. The authors proposed that their observations of lower ERP amplituide indicate "attenuated or abnormal auditory central processing in NIHL tinnitus patients". They also suggested that their findings "substantially support the hypothesis postulating abnormal information processing in tinnitus sensation".

Shiraishe, Sugimoto, Kubo, Mataugnaga, Nageishe and Simokochi (1991) reported increased amplitude in contingent negative variation, a slow negative cortical shift appearing in the fronto-central region, in a sample of tinnitus subjects. The subjects were asked to respond by pressing a key after an auditory and then a visual stimulus.

In this study the tinnitus subjects exhibited greater contingent negative variation amplitude after the start of the first (auditory) stimulus. This auditory stimulus effectively acted as a warning signal, provoking an orienting reaction. The authors suggested that the tinnitus subjects were therefore exhibiting different information processing. They did not, however, find any significant differences in the N100 and P300 evoked potentials of tinnitus subjects.

The importance of central factors in tinnitus perception has been highlighted by Jastreboff (1990) and Jastreboff and Hazell (1993). These authors proposed that tinnitus involves the whole auditory pathway and not simply the periphery. Jastreboff (1990) published a theoretical analysis of tinnitus from a neurosciences perspective. He suggested that all tinnitus, even that in which there is clear cochlear pathology, must involve abnormalities of both cochlear function and the processing of tinnitus related signals within the nervous system. He suggested that it is more useful to regard tinnitus as a disorder of perception involving central components as well as peripheral ones rather than trying to understand it as the product of a single localised generator.

Jastreboff (1990) suggested that the perception of tinnitus is different from that of external sounds. Unlike the masking of external sounds, tinnitus can be masked by pure tones or by noises at a range of frequencies, at times contra-laterally, and with intensities of masking sound that are abnormally great or small. In addition, tinnitus requires increased intensity of masking over a period of time while external sound does not require this increase (Penner & Bilger, 1992). Sometimes it is not possible to mask tinnitus. In the long term, masking of tinnitus by sounds that do not 'cover' or mask it in the auditory sense can be therapeutic. Cessation of tinnitus through masking is sometimes followed by residual inhibition. Similar responses may be associated with stimuli of different strengths from the peripheral generator. Jastreboff

(1990) suggested that in order to explain such phenomena it necessary to hypothesise that tinnitus perception involves the entire auditory pathway and in particular the plasticity of neuronal networks.

Jastreboff (1990) suggested that a number of stages in the perception of tinnitus can be differentiated; generation, detection, and perception and evaluation. Generation usually occurs at the periphery and in the majority of cases in the cochlear or the cochlear nerve. Detection occurs in subcortical centres and is based on pattern recognition. Perception and evaluation occur at the auditory cortex level with "considerable and significant participation of the limbic system, the prefrontal cortex and several other cortical areas" (Jastreboff, 1990).

Jastreboff's (1990) hypothesis reflects the concept of parallel processing within the nervous system by interconnected neuronal networks. He appealed to Goldman-Rakic's (1988) ideas of cortical organisation. The traditional hierarchical model suggests that raw sensory input is processed in the primary cortex and progresses through stages of processing to the frontal association areas where different data are integrated. Goldman-Rakic (1988) suggested instead that functions are distributed between several parallel interconnected systems that bridge all the major subdivisions of the cerebrum. Jastreboff (1990) argued that this type of organisation offers the possibility of creating loops which "amplify the perception of tinnitus by creating positive feedback within the cortical networks".

Jastreboff and Hazell (1993) suggested that weak and abnormal activity, usually related to cochlear damage, is detected and enhanced by processing in the auditory pathways. They postulate that a process of "kindling" may occur that ultimately leads to the perception of tinnitus. Initially abnormal activity may lie below the threshold for awareness but with prolonged stimulation this activity may be enhanced and reach a threshold for discrimination. The neuronal pattern representing tinnitus is stored in the auditory memory. It is argued that attention to, or orientation to, the tinnitus may strengthen the weights between the synapses resulting in the maintenance and enhancement of the tinnitus. If strong negative emotions become linked to the abnormal neuronal activity, habituation cannot occur and the tinnitus signal is enhanced (Jastreboff & Hazell, 1993). Jastreboff (1990) stressed the importance of the prefrontal cortex by pointing to its supposed role in synthesising the inner and outer sensory worlds. He postulated that because the area represents "an endpoint for diverse afferent channels and is privy to all incoming information" it is "a candidate for the integration of sensory and emotional aspects of tinnitus". He cited the success of lobotomy operations in the 1950's as support for this idea. He further postulated that the role of the prefrontal cortex in sustaining reactions may be important in tinnitus perception. He suggested that it is possible that changes in the activity of the prefrontal cortex may lead to parallel changes in autonomic nervous system activity and so in the reaction to tinnitus. If the limbic system is not activated then the tinnitus signal is filtered out at lower levels in the auditory system. He suggested that this is what distinguishes tinnitus complainers from non-complainers. There are clear parallels between this view and the habituation model put forward earlier by Hallam et al. (1984) in which the importance of tonic arousal and the emotional significance of the stimulus is highlighted. Hallam's view that tinnitus onset can represent the process of dishabituation and that there is a feedback mechanism between orientation to tinnitus and tonic arousal and the interruption of normal activities heralded Jastreboff's and Hazell's ideas.

These studies suggest the possibility that tinnitus can lead to central changes, and that tinnitus sufferers' complaints of reduced cognitive ability may reflect such central changes. Hoke et al's (1989) work pointed the involvement of temporal lobe structures. The findings of Attias et al. (1993) also indicate the involvement of the temporal lobes and, in addition, the limbic system. Jastreboff (1990) and Jastreboff and Hazell (1993) again highlighted the involvement of the limbic system and implicate the frontal lobes of the brain in tinnitus perception. The temporal lobes, limbic system and frontal lobes all play a role in cognitive functioning. It is conceivable that the slips of concentration and memory that tinnitus patients complain of in the clinic may reflect differences in the functioning of temporal lobe, limbic system and frontal lobe areas; concentration and memory functions are thought to reside in these areas.

The following studies in this thesis seek to determine, through the use of neuropsychological tests, whether or not tinnitus patients do suffer from cognitive impairments. Such tests can reveal a difference in functioning that is not apparent from radiographic or magnetic scanning techniques. These studies therefore offer a way of investigating the issue that is distinctly different from, but parallel to, work carried out by researchers such as Hoke at al. (1989) and Attias et al. (1993), and may therefore allow further understanding of the involvement of central factors in tinnitus perception. The first study in this series (Study Four) seeks to examine the cognitive functioning of tinnitus patients by using tests of cognitive functioning that are most commonly used in a clinical setting.

Chapter 7

STUDY FOUR

AN INVESTIGATION OF COGNIIVE FUNCTIONING IN TINNITUS PATIENTS USING A RANGE OF STANDARD NEUROPSYCHOLOGICAL TESTS.

To date no systematic investigation of the cognitive effects of tinnitus has been undertaken. It is therefore not clear whether or not tinnitus sufferers do experience more difficulties with cognitive functioning than do others. This study seeks to investigate whether tinnitus patients have impaired cognitive abilities by assessing their performance on a battery of neuropsychological tests. Although any cognitive difficulties produced by tinnitus might be subtle and complex in nature, a reasonable starting point is with the administration of standard clinical neuropsychological tests. Such tests may not only reveal a deficit but help to point the way forward for further investigations. The work of Attias et al. (1993) and of Jastreboff (1990) suggests that particular attention should be given to the functioning of the frontal and temporal lobes and of the limbic system. In neuropsychological terms this implies a study of concentration and memory abilities as these are among the major cognitive functions of these structures (Lezak, 1993). It is likely that if tinnitus is associated with an impairment of cognitive functioning then because of its auditory nature the functions affected are more likely to have a considerable verbal component rather than be predominantly visuo-spatial in nature. This in keeping with the clinical complaints of tinnitus patients of slips of attention and memory. This study therefore seeks to investigate these areas of functioning in tinnitus patients. It was hypothesised that the tinnitus subjects would perform less well on standard tests of cognitive functioning than a group of hearing impaired patients attending the same hospital clinics.

Method

Design

This study uses an independent groups design with an experimental group (tinnitus group) and a control group (non-tinnitus group).

Subjects

The tinnitus (experimental) group was drawn from patients with tinnitus who were attending the departments of Neuro-Otology and Audiological Rehabilitation within the Royal National Throat, Nose and Ear Hospital, London. Tinnitus was confirmed by subjects' subjective report. Only subjects who confirmed that tinnitus was present at the time of testing were included. The control group was drawn from patients complaining of acquired hearing loss but without tinnitus who were attending the above clinics. The control group was defined in this way in order to minimise the differences, other than of tinnitus, between the groups.

All subjects were between the ages of eighteen and sixty. Only patients who did not have other medical conditions likely to cause cognitive dysfunction (e.g. head injury) were included. Patients taking medication or who had undergone procedures likely to cause cognitive inefficiency (e.g. psychotropic or anti-convulsant medications or ECT) were excluded. Subjects who reported dizziness were excluded as the presence of this symptom may have neurological implications with unknown consequences on cognitive functioning. Only subjects with hearing that permitted conversation in quiet surroundings were included. The tests used have been standardised on people educated within the British or American school systems. Only subjects educated within the British system were included.

Subjects were identified from their medical notes and approached while waiting for their clinic appointment. All subjects who fitted the inclusion criteria were asked to participate. The selection criteria excluded a very high proportion of patients attending the hospital clinic, and it was estimated that some eighty per cent of clinic attenders did not meet the selection criteria. The recruitment of subjects into the control group (i.e., subjects with no tinnitus) proved particularly difficult. The difficulty in obtaining suitable subjects meant that it was necessary to proceed with the study with relatively small numbers of participants. There were twenty-eight subjects in the tinnitus group and twenty-one subjects in the control group.

Approval for the study was obtained from the ethics committee of the Royal National Throat Nose & Ear Hospital.

Procedure

All subjects were assessed on a number of widely accepted and commonly used questionnaires and on neuropsychological tests that assess concentration abilities and verbal memory function.

Questionnaires:

If tinnitus patients do have greater cognitive difficulties than other people then the question arises of whether these difficulties reflect cognitive impairment that is associated with tinnitus per se., or impairment that is associated with factors such as anxiety. In order to control for the effects of anxiety, subjects completed the Speilberger State-Trait Anxiety Inventory (STAI) (Speilberger, Gousuch & Lushene, 1970). This consists of two self report scales, one for measuring State anxiety and the other Trait anxiety. State anxiety is conceptualised as a transitory emotional state characterised by subjective feelings of tension and apprehension and heightened autonomic nervous system activity. It is expected to vary in intensity and fluctuate over time. Trait anxiety refers to relatively stable individual differences in anxiety proneness, i.e. differences between people in the tendency to respond to threatening situations with an increased anxiety state. The State anxiety scale asks people how they are feeling at a particular moment in time while the Trait scale asks how they generally feel. Each scale consists of twenty statements that subjects respond to by ticking a multiple choice option. The STAI was standardised on student populations and on neuropsychiatriac and general medical and surgical patients. Speilberger et al. (1970) reported test-retest correlations for the Trait anxiety scale that are relatively high, ranging from 0.73 to 0.86. As would be expected test-retest correlations for the State scale are lower and in the order of 0.32. The reported Alpha reliability correlations for the State scale, however, range from 0.83 to 0.92. Alpha reliabilities for the Trait scale are equally high ranging from 0.86 to 0.92. Alpha reliability coefficients are higher for the State scale when it is administered under conditions of psychological stress. Item remainder correlations for the State scale range from 0.45 to 0.55, and for the Trait scale from 0.46 to 0.54. Speilberger et al. (1970) reported evidence on the concurrent validity of the Trait scale in the form of correlations with the IPAT Anxiety Scale (0.75 to 0.76), the Taylor Manifest Anxiety Scale (0.79 to 0.83) and the Zuckerman Affect Adjective Checklist (0.52 to 0.58). As evidence for the construct validity of the State scale, Speilberger et al. (1970) reported on variations in scores when the scale was administered under conditions of increasing psychological stress. For men the mean scores for the scale rose from 40.02 to 54.99 with a critical ratio of 24.14 and a point biserial correlation of 0.60. For women the mean score rose from 39.36 to 60.51 with a critical ratio of 42.13 and point biserial correlation of 0.73.

Subjects were also asked to complete the Cognitive Failures Questionnaire (Broadbent, Cooper, FitzGerald & Parkes, 1982). This consists of a list of 25 questions about problems of concentration experienced in every day life. The authors described the questionnaire as measuring "minor everyday slips or errors" and "absentmindedness" involving disorders of attention, of memory and of the control of thought or action. They summarised these types of lapses with the term "cognitive failure" to describe a general disturbance of control. Broadbent et al. (1982) reported that the CFQ closely correlates with other self assessment measures of cognitive failure such as the Absent-mindedness questionnaire (r = 0.62) developed by Reason (1981) and the Short Inventory of Memory Experiences (r = 0.59) by Hermann and Neisser (1978). It is not, however, closely related to achievement on objective tests of memory or identification or recognition tasks (correlation scores not supplied) or to intelligence as assessed using the Mill Hill Vocabulary Scale (r = - 0.157) and the Raven Progressive Matrices (r = - 0.15). The authors claimed that some external validity for the questionnaire can be derived from a number of sources. They found significant correlations between subjects' CFQ scores and their partners' judgements of them as measured on parallel questionnaire the "CFQ for others" (r = 0.315 for husband's CFQ; r = 0.360 for wife's CFQ). The authors also noted that ECT patients obtained higher CFQ scores, as did student nurses who subsequently failed their exams. Broadbent et al. (1982) reported test-retest correlation values for the CFQ of r = 0.824 with an interval of sixty-five weeks, and of r = 0.54 with a sixteen month interval. The CFQ has a multiple choice answer system with a five point scoring scale. A total score was derived for this study.

Neuropsychological tests:

In order to control for general intellectual ability, subjects were asked to complete the National Adult Reading Test (NART) (Revised Version) (Nelson, 1982). This test is commonly used to provide an estimate of premorbid intellectual ability. The subject is presented with, and asked to read aloud, a list of fifty irregular words in use in the English Language. The test is scored in terms of the number of errors of pronunciation and an estimated premorbid IQ is derived from the score. The NART has a split-half reliability of 0.93 (Nelson, 1982). O'Carroll (1987) has reported inter-rater reliabilities of between 0.96 and 0.98 for the NART, and test-retest reliability of 0.98 has been reported by Schlosser and Ivison (1989). The validity of the NART as a reflection of intellectual ability was demonstrated by Crawford, Stewart, Cochrane, Parker and Besson (1989) who showed that the test loads highly (0.85) on 'g', the general factor of intelligence that emerges from factor analysis of the Wechsler subtests.

The Digit Symbol Substitution Test, a subtest of the Wechsler Adult Intelligence Scale (Revised Version) (Wechsler 1981), was also administered. It measures psychomotor function through the use of a coding task. This subtest is considered more sensitive to brain damage than the other WAIS-R subtests and tends to be sensitive to brain lesions regardless of their location. (Hirschenfang, 1960; Glosser, Butters & Kaplan, 1977). Wechsler (1981) reports the test-retest reliability of the Digit Symbol Substitution subtest to be 0.86 for subjects up to the age of thirty-four years of age, and 0.82 for older subjects. He reports a split half reliability of 0.82 for the subtest. The subject is presented with a set of blank squares each randomly paired with a number from one to nine. The subject is given a key that pairs each number with a nonsense symbol. The task is to fill in each blank square with the symbol that it is paired within the key. The subject is allowed ninety seconds to complete as many squares as possible. The total number of correctly coded squares is recorded.

The Graded Difficulty Arithmetic Test (Jackson & Warrington, 1986) is a test of ability to add and to subtract at speed. The test focuses on the manipulation of arithmetical facts and, in contrast to other arithmetic tests, minimises reasoning skills. The test was standardised on normal control subjects and subjects with left or right cerebral lesions. Jackson and Warrington (1986) reported that it was found to discriminate subjects with left hemisphere lesions from those in the other groups indicating its validity as a measure of cognitive functioning. The test may be viewed as a test of information processing ability. Jackson and Warrington (1986) reported significant correlations with the Wechsler Adult Intelligence Scale (WAIS) Digit Span (r = 0.651) and Arithmetic (r = 0.739) sub-tests and with the NART (r = 0.667) for the control group. A larger number of subjects with left hemisphere lesions were identified as impaired on The Graded Difficulty Arithmetic test than on the WAIS Arithmetic test. Reliability data are not stated for the Graded Arithmetic test. It involves the presentation of twelve addition and twelve subtraction tasks in order of increasing difficulty. Ten seconds are allowed for the correct solution of each task.

The Letter Cancellation Test (Lezak, 1983) assesses sustained attention and vigilance. The subject is presented with an array of letters randomly ordered and tightly printed. The task is to discover and cross out every example of a given letter; the letter 'p' was used in this study. Letter cancellation has been found to discriminate Korsokoff and Parkinson Disease patients in terms of time taken to perform the task and the number of errors made (Talland & Schwab, 1964; Talland, 1965; Horne, 1973).Talland and Schwab (1964) suggested that impairment on this test reflects a deficit of central programming. In this instance the test was scored in terms of the time taken to complete the task and the number of errors of omission and of non-target letters crossed out.

A Verbal Fluency Test, the Controlled Word Association Test (Benton, 1968; Benton, Hamsher, Varney & Spreen, 1983) was also administered. The test requires the subject to say aloud as many words as possible beginning with a particular letter (designated by the researcher) in one minute. The subject must not include proper nouns, numbers, or repeat the same word with a different suffix. The procedure is repeated with two further letters. Spreen and Strauss (1991) describe the inter-scorer reliability as "near perfect". Test-retest reliability has been reported as 0.88 for adults by desRosiers and Kavanagh (1987). Several studies have reported that the test is sensitive to frontal lobe damage, e.g. Miceli, Caltagirone, Gainotti, Masoullo, and

Silveri (1981) and Bruyer and Tuyumbu (1980). Reduced ability to generate words has also been associated with Alzheimer's type dementia (Miller & Hague, 1975). Verbal Fluency has, however, been found to hold up when symptoms of emotional disorder mimic organic deterioration (Kronfol, Hamsher, Digre & Waziri, 1978); this is particularly relevant in the present study. In this study the letters C, F and L were used and the total number of words elicited was noted.

The Trail Making Test (Reitan, 1958) is a test of speed for visual search, attention, mental flexibility and motor function. The test is considered highly sensitive to brain injury (O'Donnell, 1983; desRosiers & Kavanagh, 1987). The test is given in two parts, A and B. In part A the subject is asked to draw lines to connect consecutively numbered circles randomly arranged on a sheet of paper. In part B the task is to connect consecutively numbered and lettered circles by alternating between the numbers and the alphabet. Goldstein and Watson (1989) assessing various neurological groups found reliability coefficients ranging from 0.69 to 0.94 for Part A, and from 0.66 to 0.86 for Part B. The time taken to complete each part of the test is recorded and in this case the number of errors made was also noted. Part B is considered the more sensitive part of the test.

The Rey Auditory Verbal Learning Test (RAVLT) (Rey, 1964) is sensitive to verbal memory deficits in a variety of patient groups (Lezak, 1983; Bigler, Rosa, Schultz, Hall & Harris, 1989). This test assesses a number of aspects of verbal memory functioning. It provides a measure of immediate word span, of the ability to learn verbal information over a series of trials and of ability to recall this information after a distraction. The test consists of five presentations of fifteen words, with immediate recall on each occasion. A second list of fifteen words is then presented with immediate recall as a distraction. The subject is then asked to recall the original list without further presentation. The number of words recalled at each stage is noted. The test has a test-retest reliability in the order of 0.55 (Snow, Tierney, Zoritto, Fisher & Reid, 1988). The present study focused on the number of words recalled after the first presentation (Trial 1), after the fifth presentation (i.e. the final learning trial) (Trial 5) and the number recalled after the distraction task (Trial 6). The difference between the final and the first learning trials was calculated to give a measure of learning over the course of the test (Trial 5- Trial 1). The mean number of words recalled over the first five trials was also calculated (Mean of 1 to 5).

In addition all subjects were asked whether they judged themselves to have cognitive difficulties or not and their responses noted in a yes or no format. The level of hearing loss at 250Hz, 500Hz, 1K, 2K and 4K as measured using pure tone audiometery was noted from subjects' medical records. When available the tinnitus matching and masking levels were also noted from medical records.

Statistical Analyses

Analyses were conducted using SPSS for Windows. The analyses included descriptive statistics, chi-square tests, Mann Whitney tests, t-test tests for independent samples, Pearson product moment correlations, discriminant function analysis and analysis of covariance. Two tailed tests of significance were employed throughout.

Results

The tinnitus group consisted of seventeen male and eleven female subjects. The control group consisted of eleven male and ten female subjects (Table 4.1). Fifteen of the twenty-eight subjects in the tinnitus group reported suffering from difficulties in cognitive functioning. Ten of the twenty-one subjects in the control group reported these problems. A Chi-Square test revealed that there was no significant difference between the groups in terms of the number of subjects who reported having difficulties in cognitive functioning ($X^2 = 0.02$, $p = 0.886$).

	Tinnitus Group		Control Group			
	N=28		N=21			
Gender	17M/11F		11M/10F			
Age	Mean	SD	Mean	SD	t	p
	42.38	10.41	38.75	11.14	1.12	n.s.

Table 4.1. Age and sex of subjects

There was no significant difference between groups in the time since the onset of their audiological symptoms (Table 4.2). The mean hearing loss of the control group was significantly greater than that of the tinnitus group. This was true for hearing loss in the best ear ($t = -2.48$; d.f. = 45, $p < 0.05$) and in the worst ear ($t = -2.67$; d.f. = 45, $p < 0.01$) (Table 4.2). This reflects the difference in the main complaints of the two groups.

	Tinnitus Group		Control Group			
	Mean	S.D.	Mean	S.D.	t	p
Months since onset	62.92	66.59	48.68	30.35	0.96	n.s.
Hearing Loss dB						
Best ear	25.52	17.77	40.06	22.40	-2.48	<0.05
Worst ear	32.86	22.49	50.29	21.57	-2.67	<0.01

Table 4.2. Duration of symptoms and level of hearing loss.

The two groups were closely matched in terms of general intellectual status (Table 4.3) with the mean scores for both groups falling within the "Bright Normal" range (110-119) of intellectual functioning.

The tinnitus group obtained significantly higher scores for Trait anxiety on the STAI ($t = 2.53$; d.f. = 40, $p < 0.05$) but not for State anxiety (Table 4.3) indicating that the

Tinnitus group had a greater predisposition to respond in an anxious way to threatening situations.

The mean State anxiety scores for both groups were within a standard deviation of the published mean scores for students (which range from 35.12 to 40.01) and for neuropsychiatric patients (47.74) and general medical and surgical patients (42.38) (Speilberger et al., 1970). The mean Trait anxiety scores for both groups were also within one standard deviation of the published means for all the normative groups (students from 37.68 to 41.61; neuropsychiatric patients, 46.62; general medical/surgical patients, 41.91). The Tinnitus group's mean State anxiety score lay between the fifty-eight and sixty-sixth centile point in the distribution of scores for undergraduates. It was at the twenty-third centile in the neuropsychiatric population's distribution and at the thirty-sixth centile point in the general medical and surgical patients' distribution of scores (Speilberger et al., 1970). The Control group's State anxiety score lay between the forty-fifth and fifty-fourth centiles for students, at the fifteenth centile for neuropsychiatric patients and at the thirty-first centile point for general medical and surgical patients. The Tinnitus group's mean Trait anxiety score was between the seventy-third and seventy-sixth centile for students, at the thirty-ninth centile for neuropsychiatric patients and at the fifty-seventh centile for general medical

	Tinnitus Group		Control Group			
	Mean	SD	Mean	SD	t	p
NART IQ Equivalent	111.51	8.60	111.85	10.30	-0.12	n.s.
State Anxiety	37.04	9.68	34.10	8.27	1.08	n.s.
Trait Anxiety	43.08	12.59	35.14	8.22	2.53	<0.05

Table 4.3. Intellectual and Emotional status of subjects.

and surgical patients. This indicates that the Tinnitus group was reporting relatively high levels of Trait anxiety. The mean Trait anxiety score for the Control group was lower; it lay between the fortieth and forty-sixth centiles for students, and at the nineteenth and thirty-first centiles for the two patient groups respectively.

The tinnitus group also obtained significantly higher scores on the Cognitive Failures Questionnaire ($t = 2.17$; d.f. = 45, $p < 0.05$) (Table 4.4) indicating that there was a greater perception of cognitive mishap among the Tinnitus group.

Tinnitus Group		Control Group			
Mean	SD	Mean	SD	t	p
41.88	12.27	34.65	9.76	2.17	<0.05

Table 4.4. Cognitive Failures Questionnaire Scores

There were no significant differences between the groups in terms of scores on the Digit Symbol Substitution Test or the Arithmetic test (Table 4.5).

	Tinnitus Group		Control Group			
	Mean	SD	Mean	SD	t	p
Digit Symbol Substitution	56.46	12.17	61.38	12.35	-1.39	n.s.
Arithmetic	13.32	5.56	14.33	4.46	-0.68	n.s.

Table 4.5. Performance on Digit Symbol Substitution Test and on Arithmetic Test.

The tinnitus group took significantly longer to complete the letter cancellation task ($t = 2.14$; d.f. = 42, $p < 0.05$) (Table 4.6). A Mann Whitney test indicated that there was no difference between groups in the number of errors made in letter cancellation.

There were no significant differences between the groups' scores on the Verbal Fluency test (Table 4.6); there was, however, a trend for the tinnitus group to perform less well on this measure (p = 0.065).

		Tinnitus Group		Control Group			
		Mean	SD	Mean	SD	t	p
Letter Cancellation							
	Time	156.42	53.06	131.42	27.65	2.14	<0.05
	Number of errors	3.10	3.62	2.76	3.89	0.32	n.s.
Verbal Fluency							
	Number of words	26.57	8.47	31.57	10.04	-1.89	n.s.

Table 4.6. Performance on Letter Cancellation and Verbal Fluency Tests.

There was no difference between groups in the time taken to complete the Trail Making test (Table 4.7).

	Tinnitus Group		Control Group			
	Mean	SD	Mean	SD	t	p
Trial A Time	45.50	38.13	32.52	6.43	1.54	n.s.
Trial B Time	85.44	38.29	72.00	21.75	1.44	n.s.

Table 4.7. Performance on Trail Making Test (Time taken).

A Mann Whitney test revealed that the tinnitus group made significantly more errors on Part B of the Trail Making test (Z = -2.258; p = 0.023) (Table 4.8). This would suggest that the subjects in that group had greater difficulty alternating between the number and alphabet sequences. The importance of this difference needs to be interpreted with caution. Of the twenty-one control subjects, eleven made errors on this task compared with nine of the twenty-eight tinnitus subjects; this difference was significant ($X^2 = 2.95$, $p < 0.05$), suggesting that this task was more challenging for the Control group than for the Tinnitus group.

	Tinnitus Group	Control Group	
	Number of errors	Number of errors	p
Trail A	26.75	22.67	n.s.
Trail B	28.52	20.31	<0.05

Table 4.8 Number of errors made on the Trail Making test

There was no significant difference between groups in the number of errors made in Part A of the test.

It can be seen from Table 4.9 that there were no significant differences between the groups on any of the measures derived from the Rey Auditory Verbal Learning Test.

	Tinnitus Group		Control Group			
	Mean	SD	Mean	SD	t	p
Trial 1	6.46	1.64	7.28	1.70	-1.70	n.s.
Trial 5	12.50	2.45	12.42	1.69	-0.06	n.s.
Trial 6	10.07	3.39	9.14	2.39	1.07	n.s.
Trial 5-1	5.42	1.52	5.14	1.68	1.21	n.s.
Mean of 1 to 5	10.05	1.79	9.94	1.66	0.21	n.s.

Table 4.9. Performance on Rey Auditory Verbal Learning Test

As there were significant differences between the groups in terms of hearing loss (for better and worse ears), Trait anxiety and the scores on the CFQ, a discriminant function analysis, using a stepwise procedure, was carried out in order to determine the relative importance of these variables in predicting group membership. This analysis indicated that group membership was predicted by Trait anxiety (F = 6.46; d.f.

= 1, 40, $p < 0.05$) and by hearing loss in the best ear (F = 8.24; d.f. = 2, 39, $p < 0.001$) (Table 4.10). The remaining two variables, i.e. hearing loss in the worst ear and CFQ did not then predict group membership suggesting that in this context they do not contribute information over and above Trait anxiety and hearing loss.

Step	Entered/ Removed	Wilks' Lamdba	F. equiv.	p
1	Trait Anx	0.86092	6.461	0.015
2	H.L. Best	0.70275	8.248	0.001

Table 4.10. Summary of Discriminant Function Analysis using hearing loss, Trait anxiety & CFQ scores.

As the discriminant function analysis indicated that group membership was predicted by Trait anxiety and hearing loss in the best ear, analyses of covariance were carried out on the scores for the letter cancellation task (time) using each of these variables as a co-variate. The difference between the groups was in the order of a non-significant trend ($p = 0.062$) when Trait anxiety was used as a co-variate. Similarly, there was a non-significant trend ($p = 0.074$) when hearing loss (best ear) acted as a co-variate. This suggests that the poorer performance of the tinnitus group on the letter cancellation task was influenced by Trait anxiety and by hearing loss.

The relationship between CFQ, Speilberger anxiety scores and hearing loss was further investigated using a Pearson product moment correlation analysis. The results of that analysis, using both groups of subjects combined, are presented in Table 4.11. There was a significant correlation between Trait Anxiety and CFQ score ($r = 0.5311$, $p < 0.001$) and between CFQ score and hearing loss in the better ear ($r = 0.300$, $p < 0.05$). There was also a significant correlation between Trait anxiety and hearing loss in the better ear ($r = 0.3326$, $p < 0.05$).

	HLWorst	HLBest	AnxState	AnxTrait	CFQ
HLWorst		.85 (47) p= .000	.15 (43) p = .333	.23 (43) p = 144	.19 (45) p = .196
HLBest			.05 (43) p = .741	.33 (43) p =.029	.30 (45) p = .045
AnxState				.52 (44) p =.000	.13 (45) p = .412
AnxTrait					.53 (44) p.000
CFQ					

Table 4.11. Pearson Product Moment Correlations between Hearing loss, STAI and CFQ scores.

While these analyses again suggest that there is a significant relationship between CFQ scores and Trait anxiety they also indicate that not all of the variance within the CFQ scores is accounted for by Trait anxiety. This is also true for the relationship between CFQ and hearing loss scores. These findings also suggest that CFQ is more closely related to Trait rather than State anxiety.

The relationships between tinnitus matching and masking scores and the other measures of emotional state and cognitive functioning were examined using Pearson product moment correlation analyses. A significant correlation between the tinnitus matching scores and the CFQ scores ($r = 0.4965$; $p < 0.05$) was found suggesting a relationship between tinnitus subjects' perceptions of cognitive vulnerability and the level of external noise required to match subjects' tinnitus. A significant relationship was also found between the time since the onset of tinnitus and the masking level ($r = 0.3877$; $p < 0.05$) suggesting that the longer the time since onset the more external sound is required to mask it. No other significant correlations were observed.

Discussion

The two groups were closely comparable in terms of age and in terms of general intellectual level as measured by the reading test. They were distinguished by the degree of hearing loss; this is to be expected given the composition of the groups.

There was no significant difference between groups in State anxiety levels but a significant difference in Trait anxiety was found. It is somewhat surprising that Trait and not State anxiety distinguished the groups. In Study One, emotional disturbance was observed in a higher proportion of tinnitus patients than patients whose main complaint was hearing loss; this disturbance was apparent on a measure of emotional state - the GHQ. However, personality differences implying elevated "psychopathology" have previously been noted in both tinnitus (Reich & Johnson, 1984) and hearing impaired patients (e.g. Stephens, 1980; Coren & Harland, 1995). Hallam et al. (1983), however, suggested that elevated scores on personality inventories are more closely related to the number of symptoms experienced by patients rather than simply to tinnitus. It was also noted in Study One that psychological disturbance was related to the number of symptoms reported by subjects. Many of the Tinnitus subjects in this study also had a degree of hearing loss, while none of the hearing impaired Control subjects had tinnitus. It is therefore possible that the higher level of Trait anxiety in the Tinnitus group reflects the number of symptoms experienced rather than simply the presence of the particular symptom. This would be in keeping with the view that psychological disturbance is related to general health rather than to specific symptoms. It is, nonetheless, surprising that addition of extra symptoms did not lead to higher State anxiety. It is also interesting to note that the finding of Study One of a higher level of psychological disturbance among subjects whose main complaint is tinnitus than among those whose main complain is hearing loss is reiterated by the findings of this study.

The tinnitus group also obtained significantly higher scores on the Cognitive Failures Questionnaire (CFQ). Broadbent et al. (1982) proposed that the CFQ measures a "general liability to failure". Broadbent et al. (1982) point out that people with a high rate of cognitive failure are also likely to report a high incidence of more conventional affective symptoms. They reported significant tau correlations between the CFQ and a modified Middlesex Hospital Questionnaire (MHQ) (Crown & Crisp 1966) ranging from 0.221 to 0.541 depending on the population. They noted, however, that while changing levels of stress in one of their subject populations (student nurses) were reflected in changing MHQ scores there was no covariation in the CFQ. They argued that cognitive failures do not appear to be a direct result of emotional distress but that a high CFQ score represents a vulnerability factor making the individual less able to resist the effects of stress. This is in line with the view that stress has its major effects on those who cannot cope cognitively. Broadbent et al. (1982) cite a finding by Reason (1981) that people do not report particular stress at the time of making cognitive failures as part of their argument that the CFQ is not a measure of emotional state as much as a measure of a stable trait. Broadbent et al. (1982) report that the CFQ correlates significantly although relatively weakly with the Neuroticism scale ($r = 0.277$) and (negatively) with the Lie scale ($r = - 0.177$) of the EPQ in a group of student nurses. A correlation of $r = 0.65$ between the CFQ and Speilberger Trait Anxiety was also reported by Broadbent et al. (1982). In the present study CFQ scores did not distinguish the groups after Trait anxiety and hearing loss had been entered into a stepwise Discriminant Function Analysis. This suggests that the CFQ may not be measuring a separate factor from these other variables. The observed correlation ($r = 0.5331$) between CFQ and Trait anxiety scores also supports the idea that these variables are related. The correlation observed in this study is however slightly weaker than that reported by Broadbent et al. (1982). It would therefore seem that the CFQ is measuring something related to, but not entirely synonymous with, Trait anxiety. Broadbent et al. (1982) suggest that a high CFQ score reflects "some defect of overall control". The fact that the tinnitus group scored more highly on this measure is in keeping with tinnitus patients' complaints of difficulties in cognitive functioning.

The finding of a significant correlation between Trait anxiety and hearing loss (in the better ear) and between CFQ scores and hearing loss for both groups supports the idea of a link between the degree of hearing impairment and personality disturbance. The present data, however, do not indicate the cause and effect relationship between these variables.

Overall, the tinnitus group performed at a significantly poorer level than the control group on only two neuropsychological measures of cognitive functioning, the time taken to complete the letter cancellation task and the number of errors made in Part B of the Trail Making Test. As a greater number of subjects in the control group made errors on Part B of the Trail Making Test it would be unwise to place much emphasis on this finding. It might be argued that it is surprising that subjects from both groups who are not manifestly "brain damaged" should make any mistakes on a relatively straight forward test of cognitive ability such as the Trail Making test. The effects of multiple testing also need to be born in mind, i.e. with so many comparisons being made it is possibility that at least one significant difference arose by chance.

The significant difference between groups on the time taken to complete the letter cancellation test requires careful consideration. The letter cancellation task represents a test of vigilance, and a deficit in this ability would be in keeping with the clinical complaints of tinnitus patients. The difference between groups on this measure, however, was not apparent when analyses of covariance allowed for the effects of Trait anxiety and hearing loss separately. The influence of anxiety on cognitive functioning has been widely recognised (e.g. Eysenck, 1985; Mathews & MacLeod, 1985; Butler & Mathews, 1983). The present findings may simply reflect the findings of other studies showing that anxiety impairs cognitive functioning. It seems that anxiety is deleteriously effecting the performance of tinnitus subjects on a test of concentration. However, the non-significant trend for the tinnitus group to perform more poorly on the letter cancellation task after controlling for anxiety suggests that the poorer performance of tinnitus patients may not be entirely accounted for by the effects of anxiety.

The possible influence of hearing loss on cognitive functioning is less easily recognised or understood. Some hearing impaired people complain that the effort of listening carefully and of lip-reading and studying other aspects of non-verbal communication is tiring and difficult to sustain. When tired their ability to communicate deteriorates. There is a debate about the association between hearing loss and dementia in elderly people. However, in the present study the difficulties were observed in a populations of adult rather than geriatric deafened people. The present results suggest that hearing impairment had a detrimental effect on the tinnitus subjects' performance on the letter cancellation task. Taken alongside the finding that subjects from the control group had difficulties on the Trail Making test, this suggests that hearing impairment may have an impact on cognitive functioning.

There were no significant differences between groups for the other neuropsychological tests. However, the tinnitus group tended to perform more poorly on the Verbal Fluency test ($p = 0.065$), on the time element of Part A of the Trail Making test ($p = 0.080$) and on the first trial of the RAVLT ($p = 0.090$). The results of the letter cancellation task together with these trends suggests that the possibility of a deficit in the cognitive functioning of tinnitus patients should remain a focus of interest.

The comparatively small number subjects and the relatively large number of possible variables was also thought to make the use of multivariate analyses unsuitable.

Tinnitus matching levels were found to correlate positively with CFQ score while masking scores correlated with the time since the onset of the symptom. Given the apparent association between CFQ score and Trait anxiety in this study it is noteworthy that there was not a significant correlation between the latter and matching or masking levels. The data suggest a link between the cognitive vulnerability, as measured by the CFQ, and the perception of tinnitus intensity. Correlation does not imply causality. However, as tinnitus matching and masking levels are not good predictors of other aspects of tinnitus complaint, it is tempting to speculate that the cognitive vulnerability implied by high CFQ scores may allow tinnitus to have a greater impact on people and therefore to be perceived as more intense. This is broadly in keeping with the idea that stress has its major effects on those who cannot cope cognitively.

The association between masking levels and time since the onset of symptoms is surprising. The finding implies that tinnitus loudness increases with time. It should be noted, however, that the number of subjects for whom matching and masking scores were available is very small (n = 17) and therefore any conclusions derived from such data must be speculative. The present finding merits replication with a larger group of subjects. The fact that there were no significant correlations between the matching or masking scores and the standard tests of cognitive ability suggests that these audiometric measures are not informative about this aspect of tinnitus complaint. This is in keeping with the poor associations between matching and masking scores and other aspects of tinnitus complaint.

While the findings of this study do not support the hypothesis that tinnitus patients perform more poorly on standard tests of cognitive functioning they do leave the question open. There are a number of possible reasons why this study did not reveal more distinct deficits in the cognitive functioning of tinnitus patients. Firstly, the cognitive tasks were not very demanding and were of relatively short duration; it might be that subjects were able to "rally" themselves to complete these tasks. It is also the case that the number of subjects was relatively small making it less likely that significant differences between groups would be found. It is conceivable that the use of either more demanding cognitive tasks, or a larger subject population, would reveal more robust differences. These proposals form the basis for the next study (Study Five).

Some of the findings from this study were published as: McKenna, L., Hallam, R. S. & Shurlock, L. (1995) Cognitive functioning in tinnitus patients. Proceedings of the Fifth International Tinnitus Seminar, Portland, USA.

Chapter 8

STUDY FIVE

AN INVESTIGATION OF COGNITIVE FUNCTIONING IN TINNITUS PATIENTS USING VERBAL FLUENCY AND LETTER CANCELLATION TESTS

In Study Four, tinnitus subjects performed less well than a control group on a letter cancellation task although this difference was reduced to a non-significant trend when the influences of Trait anxiety and hearing loss were taken into account through an analysis of covariance. There was also a non-significant tendency for tinnitus subjects to perform less well on a number of other tests of cognitive functioning.

The possibility that tinnitus patients do have compromised cognitive functioning remains open as there are a number of possible reasons why a statistically significant difference was not observed between the groups on the standard tests. A possibility is that tinnitus patients' complaints of cognitive difficulties would be apparent only on more demanding tasks; it might be that they are able to 'rally' their resources to permit the completion of shorter and less demanding tasks. In addition, the number of subjects that took part in Study Four may have been too small to show an effect.

As the letter cancellation task distinguished the groups in Study Four, this task was selected for further study but in a more demanding form. Of the other standard tests used in Study Four, the Verbal Fluency test was the one that came closest to statistical significance ($p = 0.065$). This study seeks to examine the issue again by repeating the Verbal Fluency Test with a larger sample size and also using a modification of that test that places greater demands on the subject. As in Study Four, it was hypothesised that tinnitus subjects would perform less well than a control group on these tests.

Method:

Design

This study used an independent groups design with an experimental group (tinnitus group) and a control group (non-tinnitus group).

Subjects

In this study two new groups of subjects were selected from the same source, in the same way, and according to the same criteria as in Study Four. The selection criteria again excluded a very high proportion of patients (75 - 80%) attending the hospital clinic. Twenty-two new subjects formed the tinnitus group and seventeen new subjects formed the control group in this study. In addition, in order to create a larger subject group for some of the analyses, relevant data gathered in the present study were combined with those gathered in Study Four (see below).

Procedure

Subjects were asked to complete the following questionnaires and tests of cognitive functioning.

Questionnaires:

In order to control for the effects of anxiety, subjects completed the Speilberger State-Trait Anxiety Inventory (STAI) (Speilberger et al., 1970). This questionnaire is described in Study Four.

Subjects were also asked to complete the Cognitive Failures Questionnaire (CFQ) (Broadbent et al., 1982). Again this questionnaire is described in Study Four.

Neuropsychological Tests:

In order to control for general intellectual ability, subjects were asked to complete the National Adult Reading Test- Revised Version (NART) (Nelson, 1982). This test is described in Study Four.

The Letter Cancellation test (Talland & Schwab, 1964) is also described in Study Four. On this occasion a modification of the test was used. Subjects were asked to cross out every example of the letter 'p' from an array of letters that was twice the size of that used in Study Four. This modification was made in order to increase the demands of the task. The time taken to complete the task and the number of errors (missed target letters and letters incorrectly deleted) was recorded.

Subjects were asked to complete a number of tests of Verbal Fluency. The particular test used was the Controlled Word Association Test (Benton, 1986); this was used in a standard form and in two modifications designed to make the task more demanding. The standard form is described in Study Four. In the first modification subjects were asked to follow the rules of the standard procedure but using six rather than three letters. The same three letters (C, F & L) used in Study Four were used first, followed by P, R and W. In the second modification subjects were asked to carry out the Verbal Fluency procedure for two minutes duration using a single letter (S). On each occasion the number of acceptable words offered by the subject was recorded.

The level of hearing loss at 250Hz, 500Hz, 1K, 2K and 4K as measured using pure tone audiometery was noted from subjects' medical records. On this occasion tinnitus matching and masking levels were not recorded because of the previous finding of a lack of relationship between them and the clinical style test scores; it was also the case that these measures were no longer routinely taken in the relevant clinics.

Statistical Analyses

Analyses were conducted using SPSS for Windows. The analyses included descriptive statistics, chi-square tests, Mann Whitney tests, t-test tests for independent samples, Pearson product moment correlations, discriminant function analysis and analysis of covariance. Two tailed tests of significance were employed throughout.

Results

A total of twenty-two new tinnitus subjects and seventeen new control subjects were assessed. There was no difference in the mean age of the two groups. A Chi-Square analysis revealed that there was no significant difference between the groups in the number of subjects complaining of cognitive difficulties.

	Tinnitus Group		Control Group			
	N = 22		N = 17			
Gender	13M/9F		8M/9F			
	Mean	S.D.	Mean	S.D.	t	p
Age	45.09	10.94	38.68	10.22	1.83	n.s.

Table 5.1. Age and sex of subjects.

The control group had their audiological symptoms for a significantly longer period of time ($t = -4.21$; d.f. = 33, $p < 0.001$) (Table 5.2). That group also had significantly poorer hearing for both best ($t = -2.20$; d.f. = 33, $p < 0.05$) and worst ($t = -2.70$; d.f. = 23, $p = < 0.05$) ears (Table 5.2).

	Tinnitus Group		Control Group			
	Mean	S.D.	Mean	S.D.	t	p
Months since onset	67.90	52.60	230.0	147.20	-4.21	< 0.001
Hearing Loss dB						
Best ear	25.47	22.27	46.06	31.36	-2.26	< 0.05
Worst ear	33.94	28.22	63.37	36.31	-2.70	< 0.01

Table 5.2. Duration of symptoms and level of hearing loss.

The two groups were closely matched in terms of intellectual ability as measured by the NART (Table 5.3).

As in Study Four the Tinnitus group obtained significantly higher Trait anxiety scores ($t = 2.74$; d.f. = 37, $p < 0.01$) on the STAI (Table 5.3). There was no significant difference between the groups on State anxiety scores.

	Tinnitus Group		Control Group			
	Mean	S.D.	Mean	S.D.	t	p
NART IQ Equivalent	107.31	10.08	110.52	9.14	-1.03	n.s.
State Anxiety	40.45	11.38	34.64	8.17	1.78	n.s.
Trait Anxiety	46.90	11.36	37.58	9.37	2.74	< 0.01

Table 5.3. Intellectual (NART) and Emotional (STAI) Status of the subjects.

The mean State anxiety scores for both groups were within a standard deviation of the published norms. The mean Trait anxiety score for the tinnitus group was just over one standard deviation higher than the published norms for college freshmen; it was within a standard deviation of the mean scores for neuropsychiatric and general medical and surgical patients (Speilberger et al., 1970). The mean Trait anxiety score for the control group was within a standard deviation of all of the published norms. The Tinnitus group's mean State anxiety score was between the seventy-fourth and the seventy-sixth centile point on the distribution of scores for undergraduates; it was at the thirtieth centile for neuropsychiatric patients and at the forty-third centile for general medical and surgical patients (Speilberger et al., 1970). The mean State anxiety score for the Control group lay between the fiftieth and fifty-ninth centiles for undergraduates and at the eighteenth and thirty-third centiles respectively for the two patient groups. The Tinnitus group's mean Trait anxiety score was again relatively high; it lay between the eighty-fourth and eighty-sixth centiles for undergraduates, at the fifty-first and sixty-eighth respectively for the two patient groups. The mean Trait anxiety score for the Control group lay at the fifty-fifth centile point for undergraduates and at the twenty-fourth and fortieth centiles for the respectively for the patient groups.

There was no difference in the mean CFQ scores between groups (Table 5.4). This is in contrast to the results of Study Four. On this occasion both scores are higher than those observed in Study Four. The Control group's score suggests that they also perceive themselves as having difficulties in cognitive functioning.

Tinnitus Group		Control Group			
Mean	S.D.	Mean	S.D.	t	p
47.77	12.17	42.05	9.24	1.61	n.s.

Table 5.4. Cognitive Failures Scores.

The tinnitus group took significantly longer to complete the letter cancellation test ($t = 2.11$; d.f. = 36, $p < 0.05$) (Table 5.5) indicating that they had greater difficulty with this test. A Mann Whitney test revealed that there was no difference in the number of errors made by the groups in completing the letter cancellation test (Table 5.5).

	Tinnitus Group		Control Group			
	Mean	S.D.	Mean	S.D.	t	p
Time	300.63	79.86	252.43	60.751	2.11	0.042
Number of errors	17.54	20.65	12.00	13.46	0.94	n.s.

Table 5.5. Letter Cancellation Test scores.

No significant differences were observed between the performance of the two groups on the standard Verbal Fluency test or on either of the modifications of this test used in this study (Table 5.6).

	Tinnitus Group		Control Group			
	Mean	S.D.	Mean	S.D.	t	p
3 letters	37.86	13.26	42.29	12.03	-1.08	n.s.
6 letters	72.68	22.58	83.237	23.18	-1.43	n.s.
S x 2mins	26.54	9.15	29.12	7.83	-0.91	n.s.

Table 5.6. Scores for the standard Verbal Fluency test and its modifications.

As there were significant differences between the groups in terms of hearing loss (for better and worst ears), Trait anxiety and the time since the onset of symptoms, a discriminant function analysis, using a stepwise procedure, was carried out in order to determine the relative importance of these variables in predicting membership of the groups. This analysis indicated that group membership was predicted only by the time since the onset of symptoms ($F = 20.40$; d.f. = 1, 32, $p < 0.0001$) (Table 5.7).

Step	Entered/ Removed	Wilks' Lamdba	F. equiv.	p
1	Time since onset of symptoms	0.61063	20.40	0.0001

Table 5.7. Summary of Discriminant Function Analysis using scores for hearing loss in better and in worse ear, Trait anxiety & time since onset of symptoms.

The remaining three variables, i.e., hearing loss in the worst ear and in better ear and Trait anxiety did not then predict group membership indicating that they are not independent from the duration of the symptoms when predicting group membership.

As the control group had their symptoms for a longer period of time than the tinnitus group it is possible that the tinnitus group's performance on the cognitive tests was related to the fact that they had less time in which to adapt to or habituate to their symptom and that their higher level of Trait anxiety was related to this. It is also possible that the poorer hearing of the control group is related to the longer duration of that group's symptoms. As the discriminant function analysis indicated that the duration of the symptoms was the most powerful predictor of group membership the data from the cognitive function tests were re-analysed using this variable as a co-variate. The difference between groups in the time taken to complete the letter cancellation task became non-significant; this suggests that the shorter time that the Tinnitus group had had their symptoms did affect their performance on this task. The differences in the scores from the Verbal Fluency tests remained non-significant when re-analysed using duration of symptoms as a co-variate.

Although the discriminant function analysis indicated that the duration of symptoms was the most powerful predictor of group membership the other variables included in that analysis remain of interest. It might be expected that Trait anxiety would have an effect on performance on cognitive function tests, and the findings of Study Four suggested that hearing loss might also be influential in this respect. The data from the cognitive function tests were therefore re-analysed using an analysis of covariance with Trait anxiety and hearing loss in better and in worse ear each acting as a separate co-variate. The differences observed in the cognitive test scores were non-significant when Trait anxiety was used as a co-variate. When hearing loss in the better ear was used as a co-variate the difference in scores on the standard (3 letter) Verbal Fluency test was significant between groups ($F= 5.382$; d.f. =1, 32, $p < 0.05$) as was the difference in the six letter version of the test ($F = 6.823$; d.f. = 1, 32, $p < 0.05$). The group difference in scores on the two minutes (letter S) Verbal Fluency test and the letter cancellation test was non-significant. When hearing loss in the worse ear was used as a co-variate, the differences in scores on the standard (3 letter) Verbal Fluency test became significant ($F = 5.989$; d.f. = 1, 32, $p < 0.05$) as did the difference in scores on the six letter version of the test ($F = 7.753$; d.f. = 1, 32, $p < 0.01$). The difference in scores on the two minutes (letter S) version of the test emerged as a non-significant trend ($p = 0.074$) following this analysis. The difference in letter cancellation test scores was non-significant. These findings suggest that the Tinnitus group had poorer Verbal Fluency test performance but that hearing loss acted to mask this difference between the groups, i.e. hearing loss also contributed to poor performance on these tests.

In order to obtain a larger sample size the data from the standard (3 letter) Verbal Fluency test in this study were combined with those from the same test in Study Four. In this combined data set there were forty-eight subjects in the tinnitus group and thirty-six in the control group. All subjects were from the same source and the same test procedure was used. The Verbal Fluency data were analysed together with combined data on age, duration of symptoms, hearing loss, the NART, the STAI and the CFQ (see Table 5.8). The two groups were closely matched in terms of intellectual ability as measured on the NART. There was a significant difference between the ages of the two groups; the Tinnitus group was older (t = 2.08; d.f. = 82, p < 0.05).

	Tinnitus Group		Control Group			
	Mean	S.D.	Mean	S.D.	t	p
Age	43.62	10.63	38.72	10.78	2.08	< 0.05
Months since onset	65.20	60.01	131.57	135.81	-2.70	< 0.01
H.L. Best ear	25.50	19.51	42.72	26.51	-3.39	< 0.001
H.L Worst ear	33.31	24.72	56.10	29.34	-3.82	< 0.001
NART IQ	109.63	9.43	111.26	9.69	-0.79	n.s.
State anxiety	38.63	10.53	34.35	8.11	2.04	< 0.05
Trait anxiety	44.91	12.04	36.23	8.72	3.82	< 0.001
CFQ	44.53	12.45	38.05	10.11	2.58	< 0.05
Verbal Fluency 3 letters	31.54	12.12	36.36	12.09	-1.85	n.s.

Table 5.8. Combined data from Studies Four & Five for Verbal Fluency (3 letters), age, duration of symptoms, hearing loss, the NART, the STAI, and the CFQ.

The control group had their symptoms for a longer period of time
(t = - 2.70; d.f. = 81, p < 0.01) and had poorer hearing in the better ear
(t = - 3.39; d.f. = 80, p < 0.001) and in the worse ear (t = - 3.82; d.f. = 80, p < 0.001).

The tinnitus group had higher levels of Trait anxiety (t = 3.82; d.f. = 81, p < 0.001) and State anxiety (t = 2.04; d.f. = 82, p < 0.05). The tinnitus group again obtained higher scores on the CFQ (t = 2.58; d.f. = 84, p < 0.05). As can be seen from Table 5.8 there was not a significant difference between the groups in Verbal Fluency test scores.

A discriminant function analysis, using stepwise procedure, was carried out in order to determine the relative importance of age, duration of symptoms, hearing loss, anxiety and CFQ sores (i.e. the variables on which significant differences were observed) in predicting membership of the groups. This analysis indicated that group membership was predicted by hearing loss in the worst ear ($F = 14.14$; d.f. = 1, 1, $p < 0.001$), by Trait anxiety ($F = 12.50$; d.f. = 1, 2, $p < 0.001$) and by age ($F = 11.10$; d.f. = 1, 3, $p < 0.001$) (Table 5.9). The remaining variables, i.e., duration of symptoms, hearing loss in the better ear, State anxiety and CFQ did not then predict group membership. That Trait anxiety predicted group membership is in keeping with the findings of Study Four. While it is hearing loss in the worst rather than the better ear that predicts group membership in this study the importance of hearing loss in this context is again highlighted.

Step	Entered/ Removed	Wilks' Lamdba	F. equiv.	p
1	H.L Worst	0.82569	14.144	0.000
2	Trait anxiety	0.72521	12.504	0.000
3	Age	0.66124	11.100	0.000

Table 5.9. Summary of Discriminant Function Analysis using Age, Duration of symptoms, hearing loss, STAI & CFQ scores.

As hearing loss (in the worst ear), Trait anxiety and age predicted group membership in the discriminant function analysis the data from the Verbal Fluency test were analysed using an analysis of co-variance with each of these variables acting as a co-variate.

When hearing loss (in the worst ear) was used as a co-variate the difference in the groups' Verbal Fluency scores was significant ($F = 8.274$; d.f. = 1, 79, $p < 0.005$) indicating that the Tinnitus group did perform more poorly on this test and that hearing loss was masking this difference.

When Trait anxiety was used as a co-variate the difference between the groups' Verbal Fluency scores was non-significant.

When age was used as a co-variate the difference in Verbal Fluency scores was significant (F = 5.304; d.f. = 1, 81, $p < 0.05$) again indicating that the Tinnitus group performed more poorly on the test and that the greater age of that group was masking the difference between the groups' performance on the Verbal Fluency test. These findings suggest that tinnitus subjects do perform less well on the Verbal Fluency test.

The relationships between hearing loss, STAI and CFQ scores from these combined data were further investigated using Pearson product moment correlation analysis (Table 5.10). There was a significant relationship between Trait anxiety and CFQ scores ($r = 0.5718$, $p < 0.001$). These results point to the relationship between Trait anxiety and CFQ but there is again an important amount of CFQ variance that is not accounted for by Trait anxiety.

	H.L.Worst	H.L.Best	AnxState	AnxTrait	CFQ
H.L.Worst		.85 (82) p= .000	.01 (78) p = .921	.03 (78) p = .807	.10 (80) p = .356
H.L.Best			.02 (78) p = .877	.11 (78) p = .356	.11 (80) p = .330
AnxState				.65 (83) p = .000	.34 (84) p = .001
AnxTrait					.57 (83) p = .000
CFQ					

Table 5.10. Pearson Product Moment Correlations between Hearing loss (better and worse ear), STAI and CFQ scores.

On this occasion a significant relationship was also observed between State anxiety and CFQ scores ($r = 0.3433$, $p < 0.001$). The relationship is, however, weaker than that observed between Trait anxiety and CFQ scores. This again indicates that the CFQ is more closely related to Trait rather than State anxiety. There were no significant relationships between hearing loss scores and STAI or CFQ scores.

Discussion

The two groups were closely comparable in terms of intellectual level as measured by the NART. In the first part of this study, i.e. with the new sample of subjects, the groups were also comparable in terms of age. They were, however, distinguished by the degree of hearing loss; as in Study Four the control group had poorer hearing. The control group had also had their symptoms for a longer period of time. As in Study Four the tinnitus group obtained higher Trait anxiety scores and there was no difference in State anxiety scores. The discriminant function analysis indicated that the duration of symptoms was the variable that predicted group membership.

The CFQ scores found in this study were high for both Tinnitus and Control subjects. Unlike the findings from Study Four there was no difference in CFQ scores between the groups in the new sample of subjects. The groups were selected according to the same criteria and from the same sources as in Study Four so it is unlikely that these factors can account for the difference. The CFQ scores obtained by both groups in this study were higher than those observed in Study Four; the increase in the Control group's score was larger than that observed for the Tinnitus group. The Control group's CFQ score in the present study was higher than the Tinnitus group's score in Study Four. The present findings suggest that the Control group perceived themselves to have the problems that the CFQ assess to the same extent as the Tinnitus group. Both groups' scores are higher than (although within a standard deviation of) the mean scores for production workers and skilled workers reported by Broadbent et al. (1982) although lower than for student nurses.

When the data from this study were combined with those from Study Four a significant difference in CFQ scores was observed indicating the Tinnitus group's perception of greater difficulty in cognitive functioning. The scores for both groups were again higher than the mean scores for skilled and production workers reported by Broadbent et al. (1982) and lower than those reported for student nurses. The question of whether the CFQ assesses something independent from Trait anxiety and hearing loss emerges. As in Study Four the correlations between the CFQ and these other variables do indicate a considerable amount of variance within the CFQ that is not accounted for by Trait anxiety or by hearing loss. This suggests that the CFQ does measure a separate construct. In as much as the CFQ is a measure of a "general liability to failure" and of "some deficit of overall control" the present findings indicate that Tinnitus subjects have greater difficulty in this respect. Unexpectedly, they also indicate that hearing impairment is associated with compromised cognitive functioning as measured on this questionnaire.

A preliminary analysis (using t-tests) of the data from the neuropsychological tests indicated that there was a significant difference between groups on the letter cancellation task (the tinnitus group performed more poorly); no significant differences were observed on the Verbal Fluency tests. However, the picture that emerges when duration of symptoms, Trait anxiety and hearing loss are controlled for is different. When duration of symptoms acted as a co-variate, the difference in letter cancellation scores was non-significant. This suggests that the shorter time that the Tinnitus group had their symptoms affected their performance on this task; it is likely that this reflects a corresponding lower level of adaptation to the symptoms. As in Study Four, when Trait anxiety acted as a co-variate, the difference in letter cancellation test (time taken) scores was non-significant, again suggesting that performance on this task was also influenced by anxiety level.

When hearing loss (in the better ear) was used as a co-variate there were significant differences in the Verbal Fluency data, except for the two minute letter S test in which a non-significant trend was found. These findings provide evidence for the hypothesis that tinnitus is associated with impaired cognitive functioning. This pattern of results again also points to some difficulty in cognitive functioning associated with hearing impairment. This corroborates the CFQ findings.

Different effects were observed on the two tests of cognitive functioning used in this study, i.e. letter cancellation and verbal fluency. Both are tests of attention/concentration and poor performance on either may be taken as a deficit in cognitive ability. Poor performance on these tests is generally taken as a reflection of impaired frontal lobe functioning (Lezak ,1983). There is, however, an important neuropsychological difference between these two tests. Success on the letter cancellation task is heavily dependent on visuo-spatial ability and template matching. The test does have a verbal component in that it requires a minimal knowledge of the alphabet, however the Verbal Fluency test is much more dependent on verbal abilities and much less dependent on visuo-spatial ability. The present results therefore point to a difficulty in attending to and manipulating verbal information among both groups but significantly more so among the tinnitus group.

The idea that any cognitive deficit might be apparent on more demanding tasks or when larger subject groups is not well supported by these data. The difference in the scores on the six letter Verbal fluency task was more significant (when hearing loss acted as a co-variate) than that for the standard test. It was also the case that the larger data set revealed a more significant difference than the smaller set. However, the fact that a difference was observed on the standard Verbal Fluency test with small subject groups indicates that tinnitus may interfere with the performance of relatively straightforward cognitive tasks and that this is apparent when relatively small groups are studied. This difficulty in Verbal Fluency was apparent only as a trend in Study Four and was not revealed in terms of a significant difference when hearing loss acted as a co-variate in that study. It is possible that this difference may simply reflect a greater degree of difficulty in cognitive functioning among the subjects in the present study; this is suggested by the CFQ scores.

Chapter 9

STUDY SIX

THE ASSESSMENT OF COGNITIVE FUNCTIONING IN TINNITUS PATIENTS USING TWO TESTS OF FRONTAL LOBE FUNCTIONING: THE STROOP TEST AND THE PACED AUDITORY SERIAL ADDITION TASK (PASAT)

In Studies Four and Five of this thesis it was found that tinnitus subjects performed more poorly on some tests of neuropsychological functioning and had a tendency to do so on others. In the case of the letter cancellation test the poorer performance of tinnitus subjects was not apparent after the influence of anxiety was taken in to account. In the case of Verbal Fluency, however, the poorer performance of tinnitus subjects was apparent only after the influence of hearing loss had been controlled for. In as much as any difference was observed on the formal neuropsychgological tests it was apparent on tests of concentration or information processing rather than on memory tests. The implication of this is that any alteration in cognitive functioning that is associated with tinnitus might reflect a deterrioration in frontal lobe functioning rather than, say, temporal lobe functioning. It was also noted in Study Five that the poorer performance of tinnitus subjects was apparent on relatively straightforward cognitive tasks. Some tinnitus patients who are able to articulate their complaints of cognitive difficulties suggest that the problem is more apparent on routine tasks and that they can manage exceptional or demanding tasks better. It is, however, intuitively likely that a deficit in cognitive functioning would be more apparent on demanding tasks. Some "high level" or minor deficits in cognitive ability may be demonstrated only on very demanding tests. It is possible that with particularly demanding cognitive tasks any difference between tinnitus subjects and controls might be more robust and less dependent on other factors than those observed in Studies Four and Five. The present study seeks to investigate the cognitive functioning of tinnitus patients with particular regard to frontal lobe functioning and using tests that are regarded as considerably more demanding than those employed in Studies Four and Five. It was hypothesised that tinnitus subjects would perform less well on these tests than a control group of hearing impaired subjects.

Method:

Design

This study uses an independent groups design with an experimental group (tinnitus group) and a control group (non-tinnitus group).

Subjects

The subjects were drawn from the same clinical sources according to the same criteria as in Study Four. There were thirty subjects in each group. All the subjects were new, i.e. none had taken part in the earlier studies.

Approval for the study was obtained from the ethics committee of the Royal National Throat Nose & Ear Hospital.

Procedure

As in the previous studies of tinnitus and cognitive functioning all subjects were assessed on a number of widely accepted and commonly used questionnaires and neuropsychological tests.

Questionnaires:

As in Studies Four and Five the Speilberger State Trait Anxiety Inventory (STAI) (Speilberger et al., 1970) was used to control for anxiety levels. This instrument is described in Study Four.

In this study an additional measure of emotional state, the Beck depression Inventory (BDI) (Beck et al., 1961) was introduced. In the previous studies care had been taken to assess anxiety levels as the effects of that emotion on cognitive functioning are well recognised. Depression may also have an impact on cognitive functioning through general slowing effects. The BDI was therefore included in this study in order to obtain a more complete assessment of subjects' emotional status. Beck and Steer (1987) report test-retest reliabilities for the BDI that range from r = 0.48 to 0.86 for psychiatric patients; however BDI scores may be expected to change in psychiatric populations. They report higher correlations in studies of nonpsychiatric patients (r = 0.60 to 0.90). Moran and Lambert (1983) compared the content of the BDI with the criteria for diagnosing Affective Disorder according to the American Psychiatric Association's (1980) Diagnostic and Statistical Manual on Mental Disorders, 3rd edition (DSM-III). They reported that the BDI reflected six of the nine DSM-III criteria well. The BDI has been found to differentiate psychiatric patients from normals and anxiety disorder from depression (Steer, Beck, Riskind & Brown, 1986). Beck, Steer and Garbin (1988) found a mean correlation of r = 0.73 between the Hamilton Psychiatric Scale for Depression for five psychiatric populations. The BDI has twenty-one questions with a multiple choice answer format and a four point scoring system. In this study the total score for each subject was noted.

Subjects were also asked to complete the Cognitive Failures Questionnaire (Broadbent et al., 1982); this is described in Study Four.

Audiometric measures of tinnitus, i.e. matching and masking levels, did not significantly correlate with the cognitive test scores in Study Four. In order to determine whether tinnitus subjects' performance on tests of cognitive functioning is related to other aspects of tinnitus complaint, subjects were asked to complete the Tinnitus Questionnaire (TQ) (short form) (Hallam, 1996). The origins of the TQ, previously referred to as the Tinnitus Effects Questionnaire, are discussed above. This questionnaire was selected as it has known psychometric properties and was standardised in the same clinics in which the present research was conducted. The aim of the questionnaire is to assess, through self report, the main psychological effects of tinnitus along a number of dimensions. The TQ has been found to discriminate between patients whose main complaint is tinnitus and outpatients who report tinnitus (but for whom tinnitus is not the main complaint) (Hallam et al., 1988). It has been used in treatment trials (e.g. Davies, McKenna & Hallam, 1995; Jakes, Hallam, McKenna & Hinchcliffe, 1992) and scores have been found to reduce, particularly on a dimension of Emotional Distress. In this study a short form (Hallam, 1996) was used in order to minimise the demands placed upon the subjects; this was in keeping with the ethical climate of the clinics where the research took place. The short form assesses complaint along the dimensions: Emotional Distress, Sleep Disturbance, Auditory Perceptual Difficulties and Irrational Beliefs. The Emotional Distress factor assesses worries about the persistence of the noises and worries about ability to cope and about mood. The Auditory Perceptual Difficulties factor refers to the ability to discriminate speech and to locate sounds. The Sleep Disturbance factor focuses on the ability to go to sleep and stay asleep and the ability to relax. The Irrational Beliefs factor assesses worries about the significance of tinnitus for physical and mental health, about victimisation, and assesses beliefs about the relevance of psychological factors in tinnitus distress. Cronbach's alpha values for the internal consistency of this version of the TQ are 0.69 for the Emotional Distress factor, 0.75 for the Auditory Perceptual Difficulties factor, 0.73 for the Sleep Disturbance factor and 0.28 for the Irrational Beliefs factor. Correlations between the subscales ranged from 0.29 to 0.70. Cronbach's alpha for the total scale was 0.83 (Davies et al., 1995). Scores for the individual subscales and a composite score may be derived. Normative data are available for this short form (Hallam, 1996).

Neuropsychological tests:

As in Studies Four and Five, the National Adult Reading Test (NART) (Nelson, 1982) was used to control for general intellectual ability.

Subjects were asked to complete two new neuropsychological tests. The tests used on this occasion are employed in routine clinical practice. They are, however, more sensitive than those used in the previous studies and are commonly administered to when patients complain of cognitive difficulties that are not demonstrated on the types of tests used in Study Four. Both are demanding tests of information processing and are thought to be capable of revealing subtle neuropsychological deficits. Success on these tests requires the subject to suppress intuitive responses while attending to and processing less obvious aspects of the data presented. Both are regarded as tests of frontal lobe function; one has a considerable verbal component while the other is arithmetical.

The STROOP Test (Stroop, 1935) measures the ability to shift between conflicting verbal response modes. A version of the STROOP test produced by Trenerry, Crosson, DeBoe and Leber (1990) was used in this study. This version was standardised on a group of normal (i.e. without neurological disorder) adult subjects; the colour-word part of the test was found to have a test-retest reliability of $r = 0.90$. Trenerry et al. (1990) also reported that the test distinguished a group of subjects with a variety of cerebral lesions from the normal group. The material for the test consists of two cards each consisting of 112 colour names: blue, green, red and tan. Each colour name is printed in a colour other than the one it names, e.g. the word red is never printed in a matching ink colour but only in green, blue or tan coloured ink. The subject is asked to read aloud the colour names on the first card and to state the colour of the ink that each word is printed in on the second card. There is a tendency for subjects to read the words on the second card rather than to state the ink colour; the ability to suppress this tendency reflects the information processing demands of the task. The subject is instructed to read or call out the colour of the ink as quickly as possible. Subjects are allowed one hundred and twenty seconds to respond to each card. The number of correct responses made within the time limit is recorded. Care was taken to fully explain the test requirements to each subject. The STROOP test has been widely used in studies of selective attention. Subjects demonstrate interference when naming colours of words that relate to their pathology, pointing to the disruptive influence of emotion on this form of cognitive processing. A traditional colour naming STROOP test was used in this study in order to reduce the possible effects of emotional disruption of information processing.

The Paced Auditory Serial Addition Task (PASAT) - modified version (Gronwell, 1977) asses central information processing capacity similar to that seen on reaction time and divided attention tasks. It has been shown to be sensitive to mild concussions (Gronwell & Sampson, 1974) and to indicate readiness to return to work (Gronwell, 1977). It is a very sensitive test of deficit in mildly brain injured patients and it can be a demanding test for normal people. The PASAT has a split-half reliability of 0.96 implying high internal consistency (Egan, 1988). The test involves presenting the subject with a series of sixty numbers. The subject is asked to add the second number in the series to the first, and then to add the third to the second, and so on adding each number to the preceding one; in each case the subject is asked to say the answer aloud. In its original form the numbers are presented on audio tape at the rate of either one every two seconds or one every four seconds. In this case the test was modified to a visual presentation in order to avoid any possible difficulties due to hearing loss. A computer programme was written for the purpose and the numbers presented on a visual display unit (VDU). In order to ensure that the task was sufficiently demanding the numbers were presented at the rate of one every two seconds. The task was explained using a pencil and paper demonstration and then, as with the conventional audio presentation, a practice trial (on the VDU) of ten digits was included. If the subject failed to grasp the task at that point then a second practice trial was provided.

All subjects were asked whether they judged themselves to have cognitive difficulties or not and their responses noted in a yes or no format.

Approval for this study was obtained from the ethics committee of the Royal National Throat Nose & Ear Hospital. According to the requirements of that committee all subjects were given an information sheet explaining the study and their role within it. All subjects gave written consent to their participation.

Statistical Analyses

Analyses were conducted using SPSS for Windows. The analyses included descriptive statistics, chi-square tests, Mann Whitney tests, t-test tests for independent samples, Pearson product moment correlations, discriminant function analysis, analysis of covariance and MANOVA. Two tailed tests of significance were employed throughout.

Results:

The tinnitus group consisted of twelve male and eighteen female subjects. The control group consisted of sixteen male and fourteen female subjects. There was no significant difference in the ages of the two groups (Table 6.1).

	Tinnitus Group		Control Group			
	N= 30		N= 30			
Gender	12M/18F		16M/14F			
Age	Mean	SD	Mean	SD	t	p
	42.2	12.1	42.8	11.7	-0.68	n.s.

Table 6.1 Age and Sex of Subjects.

Cognitive difficulties, i.e. problems in concentration, were reported by 14 (47%) of the tinnitus group and by 9 (30%) of the control group. A Chi Square analysis revealed that there was no significant difference between the groups in the number of subjects reporting cognitive difficulties.

The two groups were not distinguished by the level of hearing loss (Table 6.2). This is in contrast to the findings in Studies Four and Five. This difference in findings may be accounted for by a considerably higher level of hearing loss in this Tinnitus group than in that observed in Studies Four and Five. The control group reported having symptoms for a significantly longer period of time (t = -3.72; d.f. = 44, p < 0.001); however, there was a very considerable range in the duration of symptoms in both groups (Table 6.2).

	Tinnitus Group		Control Group			
	Mean	SD	Mean	SD	t	p
Months since onset	105.2	80.88	225.6	158.8	-3.72	< 0.001
Hearing Loss dB						
Best Ear	45.60	24.7	40.60	21.60	0.96	n.s.
Worst Ear	56.7	29.7	57.31.	18.74	-1.46	n.s.

Table 6.2. Duration of symptoms and hearing loss

The two groups were closely matched in terms of intellectual ability as measured using the National Adult Reading Test (Table 6.3). The mean score for each group was within the "Average" range (IQ = 90 -109) of intellectual functioning.

The tinnitus group obtained significantly higher State Anxiety scores on the STAI ($t = 2.25$; d.f. = 58, $p < 0.05$) (Table 6.3). There was no significant difference between the groups' Trait anxiety scores (Table 6.3). Again this contrasts with the findings of Studies Four and Five. The Tinnitus group's STAI scores are similar to those of the Tinnitus group in Study Four. The present finding of significantly different State anxiety scores between the groups reflects lower scores on this measure for the Control group than observed in previous studies. The mean Trait anxiety score for the Tinnitus group in this study was lower than those observed in the Tinnitus groups in Studies Four and Five. On this occasion both State and Trait anxiety scores were again within a standard deviation of the mean scores for the different normative samples (Speilberger et al., 1970). The Tinnitus group's mean State anxiety score lay between the fifty-sixth and fifty-eight centile points for undergraduates, at the twenty-third centile for neuropsychiatric patients and at the thirty-sixth centile point for general medical and surgical patients (Speilberger et al., 1970). The Control group's mean State anxiety score was relatively low; it lay between the twenty-eight and thirty-third centiles for undergraduates and at the tenth and the twenty-first centiles respectively for the two patient groups. The Tinnitus group's mean Trait anxiety score was slightly higher; it lay between the sixty-fourth and seventieth centiles for undergraduates and at the thirty-third and the fiftieth centiles respectively for the patient groups. The control group's mean Trait score was between the forty-fifth and fiftieth centiles for students and at the twenty-first and thirty-third centiles respectively for neuropsychiatric and general medical and surgical patients.

	Tinnitus Group		Control Group			
	Mean	SD	Mean	SD	t	p
NART IQ Equivalent	107.53	10.63	108.46	11.55	-0.33	n.s.
State Anxiety	37.10	11.14	30.00	10.70	2.52	0.015
Trait Anxiety	41.00	10.05	36.33	11.01	1.71	n.s.
BDI	7.10	5.54	5.13	5.90	1.33	n.s.

Table 6.3. Intellectual and emotional status (STAI & BDI) status of subjects.

There was no significant difference between the groups in BDI scores (Table 6.3). The mean score for each group was within the "Normal" range (< 11) suggesting that depression was not a characteristic of these groups.

There was no significant difference between the groups scores on the Cognitive Failures Questionnaire (Table 6.4). The present score for the Tinnitus group is lower than those observed for the Tinnitus groups in the previous studies.

Tinnitus Group		Control Group			
Mean	SD	Mean	SD	t	p
38.83	14.56	39.93	13.75	-0.30	n.s.

Table 6.4. Cognitive Failures Questionnaire Scores.

There were no significant differences between the groups for either STROOP or PASAT scores (Table 6.5). There was, however, a tendency for the tinnitus group to perform less well on the STROOP test (p = 0.058).

	Tinnitus Group		Control Group			
	Mean	S.D.	Mean	S.D.	t	p
STROOP	94.68	15.53	101.80	12.55	-1.94	n.s.
PASAT	40.40	10.34	40.80	11.82	-0.14	n.s.

Table 6.5. STROOP and PASAT scores.

The recommended cut off score for the STROOP below which a subject may be classified as "cognitively impaired" is 99 for subjects between 18 and 49 years of age and 62 for subjects of 50 years and over (Trenerry et al., 1990). Ten of the thirty Tinnitus subjects and five of the Control subjects fell below the age appropriate cut off. All of the subjects who scored below the cut off point were within the under fifty years age group. The cut off point for this age group is at the twentieth centile; six of the ten Tinnitus subjects obtained scores at or below the ninth centile. A Chi-Square analysis indicated that there was no significant difference between the groups in the number of subjects scoring below the cut off point. This way of considering these data does suggest a high prevalence of cognitive impairment among both groups (and particularly so among the Tinnitus group).

In order to determine whether poor performance on the STROOP was related to emotional factors or the other variables assessed the data were further analysed by dividing all subjects into two new groups depending on whether or not their STROOP score fell below the cut off point. These new groups did not differ in terms of age, hearing loss, duration of symptoms, NART, STAI, BDI or CFQ scores (see Appendix 1 for Table of scores). No further analyses were carried out with these new groups. All of the following analyses were performed on the original Tinnitus and Control groups.

The published mean score for the PASAT is 40 (S.D. = 7) (Gronwell, 1977); the mean scores obtained by both the Tinnitus and the Control group in this study are closely in keeping with this. The scores in this study therefore indicate that neither group was impaired on this test.

As the groups were distinguished by their State Anxiety scores the data from the STROOP Test and PASAT were re-analysed using an analysis of co-variance with State anxiety acting as a co-variate. No significant group differences were revealed but there was still a non-significant tendency for the Tinnitus group to do less well on the STROOP test ($p = 0.098$). The time since the onset of symptoms also distinguished the groups and data from the STROOP and PASAT were again re-analysed using time since onset as a co-variate. This analysis did not reveal any significant differences between the groups.

As hearing loss seemed to be influential in Study Four and clearly masked the difference between groups in Verbal Fluency in Study Five it was considered important to control for its effects. The STROOP and PASAT data were therefore re-analysed using hearing loss in the better and in the worse ear each as a co-variate. These analyses did not reveal any significant differences between the groups.

The data from the STROOP test and the PASAT were re-analysed using a Multivariate analysis of variance (MANOVA) in order to determine whether a composite 'information processing' effect existed. There were no significant differences between the groups.

As in Studies Four and Five the relationship between hearing loss, STAI and CFQ scores was examined using Pearson Product Moment Correlation analysis (Table 6.6). As in Studies Four and Five there was a significant correlation between Trait anxiety and CFQ scores ($r = .3980$, $p < 0.01$). On this occasion, however, the strength of the correlation was weaker than in the previous studies, leaving a larger amount of variance in CFQ scores that is not accounted for by Trait anxiety. There was also a significant correlation between Trait anxiety and hearing loss in the worst ear ($r = 0.3184, p < 0.05$). This parallels the relationship between Trait anxiety and hearing loss that was observed in Study Four, however on that occasion hearing loss in the better ear was the important variable.

	HLWorst	HLBest	AnxState	AnxTrait	CFQ
HLWorst		.01 (50) p= .972	-.27 (52) p = .054	-.324 (52) p = .023	.08 (52) p = .593
HLBest			-.01 (50) p = .980	-.11 (50) p = .446	.05 (50) p = .722
AnxState				.76 (60) p = .000	.20 (60) p = .118
AnxTrait					.39 (60) p = .002
CFQ					

Table 6.6. Pearson Product Moment Correlations between Hearing loss (better and worse ear), STAI and CFQ scores.

The relationship between hearing loss and BDI scores was also examined using Pearson Product Moment Correlation analysis. The correlations were not significant ($r = -0.17, p > 0.05$ for hearing loss in the worse ear, and $r = -0.07, p > 0.05$ for hearing loss in the better ear).

The tinnitus group's mean scores for each of the factors within the Tinnitus Questionnaire (TQ) are presented in Table 6.7. These scores are all slightly below (but within one standard deviation of) the means quoted by Hallam (1996) suggesting that this group is similar although marginally less distressed than the normative samples.

	Mean	S.D.
Auditory Perceptual Difficulties	7.50	1.77
Emotional Distress	13.30	2.68
Irrational Beliefs	5.43	1.71
Insomnia	7.40	1.58
Total	33.63	5.37

Table 6.7. Mean TQ scores and standard deviations for tinnitus subjects.

The relationship between the TQ scores and the STROOP test, PASAT and CFQ scores were examined using Pearson product moment correlation analysis. There were no significant correlations.

Discussion

The groups in this study had somewhat different characteristics from those in the previous studies. Unlike the previous studies, the level of hearing loss in the Tinnitus group did not distinguish it from the Control group. The Tinnitus group in this study also reported lower Trait anxiety scores than its predecessors and accordingly there was no significant difference between the groups on this measure. In addition, the groups were not distinguished by their responses to the CFQ; the overlap between this measure and Trait anxiety may explain this. These scores suggest that the Control group perceived themselves to have a similar level of cognitive difficulty to the Tinnitus group. The scores from both groups were only slightly higher (and within a standard deviation) than the reported mean scores for production and for skilled workers

(Broadbent et al., 1982). The Tinnitus group's mean CFQ score was the lowest observed among Tinnitus groups in this set of studies. This score suggests that they did not perceive themselves to be particularly cognitively challenged. As subjects were selected from the same sources and according to the same criteria as in Studies Four and Five these factors cannot account for the differences in the subject profile. These differences do, however, mean that the groups are a little more closely matched than in the previous studies.

The level of correlation between Trait anxiety and CFQ scores was lower in this study than in previous ones. This again indicates that there is a considerable amount of the CFQ variance that is not accounted for by Trait anxiety; this supports the idea that the CFQ is measuring "cognitive vulnerability" that is related to but distinct from Trait anxiety.

The finding of a significant correlation between Trait anxiety and hearing loss (this time in the worse ear) for both groups supports the idea of a link between the degree of hearing impairment and this aspect of personality disturbance. This is similar to the finding in Study Four. Again, however, the data can not indicate the cause and effect relationship between these variables. It is interesting to note that no significant correlations were observed between hearing loss and State anxiety or BDI scores.

There were no differences between the groups on the PASAT and both groups' mean score was close to the published norm. This indicates that neither group was impaired on this task. There was a non-significant trend ($p = 0.058$) for the tinnitus group to perform more poorly on the STROOP test. This does not allow the hypothesis that Tinnitus subjects perform more poorly than hearing impaired subjects on this test to be accepted. However, further analysis of these data showed that many of the Tinnitus subjects obtained a STROOP test score below the cut off point for the classification of "cognitively impaired". The fact that one third of that group obtained a score at or below the twentieth centile and that six of these subjects scored at or below the ninth centile clearly distinguishes the group from the general population. This is of particular interest given that the mean score on the NART for the Tinnitus group was within the "Average" range of intellectual ability and none of that group obtained a NART score below the "Average" range of ability. This does point to a decline in information processing ability associated with tinnitus reflecting altered frontal lobe functioning. As all of the subjects (in both groups) who scored below the cut off point on the STROOP test were under fifty years of age it seems highly unlikely that their poor performance reflects an age related dementing process.

The STROOP test data again highlight difficulties in cognitive functioning among the Control group. One sixth of the Control group obtained STROOP test scores below the cut off point for "cognitive impairment". These scores distinguish this group also from the general population. As with the Tinnitus group the mean NART score for the Control group was within the "Average" range of intellectual ability. Only one subject in that group obtained a NART score below the "Average" range and that was by the equivalent of only one IQ point. These data add support to the idea that there is also a degree of cognitive slowing associated with acquired hearing loss. This is unexpected in the original context of this work. While this is undoubtedly interesting and requiring of an explanation in its own right it also suggests that the use of hearing impaired subjects as controls in a study of cognitive functioning in tinnitus patients is less than ideal.

These data do not lend clear support to the idea that any tinnitus related restriction in cognitive ability is associated with the complexity or the demanding nature of the task. The PASAT is undoubtedly a complex and demanding task; virtually every subject who does the test remarks on the difficulty. While there is some similarity in the nature of the tasks, e.g. suppression of intuitive responses, the PASAT and STROOP test make somewhat different demands of the subject; the STROOP test involves the processing of more clearly verbal information. This observation is in keeping with the difficulties that the Tinnitus groups had with the Verbal Fluency tests in the earlier studies.

The absence of any significant correlations between the TQ scores and the neuropsychological tests or CFQ scores suggests that this questionnaire does not reflect cognitive aspects of tinnitus complaint. It was suggested earlier that there is a degree of unexplained variance in the TEQ. The present findings do lend weight to the suggestion that tinnitus is associated with some difficulty in cognitive functioning and it is therefore possible that difficulties in cognitive functioning might account for some of that unexplained variance. However, the short form of the TQ was used in this study. The long form of the TQ however includes an intrusiveness factor (Hallam, 1996) that might more closely reflect patients complaints about cognitive functioning. The short form was used in this study in order to keep the demands on subjects to a minimum. It is possible that there would be a clearer relationship between the full TQ and cognitive functioning test scores. It is therefore suggested that the full TQ be used in any future research of this nature.

Chapter 10

DISCUSSION OF STUDIES 4, 5 & 6 - COGNITIVE FUNCTIONING

The aim of this series of studies was to determine whether people with tinnitus performed less well on neuropsychological tests of memory and concentration than hearing impaired controls. The findings indicate that Tinnitus subjects, compared with hearing loss Controls, have greater difficulty on letter cancellation tasks suggesting that they have poorer concentration. This difficulty, however, was no longer apparent after Trait anxiety or hearing loss had been controlled for. The data also point to cognitive difficulty among Tinnitus subjects, compared to hearing loss controls, in the form of poorer performance on Verbal Fluency tests; however, this difference between the groups was revealed only after allowance was made for degree of hearing loss. This pattern was repeated in Study Five even when subjects were presented with ostensibly more difficult versions of these tests. Both Tinnitus and hearing loss Control subjects did less well than expected on the STROOP test but both groups performed at an "average" level on the PASAT, both of which are demanding neuropsychological tests. These data do not clearly point to greater difficulty in either group when presented with more demanding cognitive tasks.

The pattern of Tinnitus subjects' responses to the CFQ contribute to the overall picture. The Tinnitus groups' and to some extent the Control groups' complaints of cognitive difficulties are reflected in their scores on this measure. These findings then do add empirical weight to tinnitus patients' complaints.

Unexpectedly, the data also pointed to concentration problems associated with acquired hearing loss. The fact that the difficulties were observed in reasonably small subject groups implies that they are important problems. The findings of Study Four also suggest that Tinnitus subjects did not have greater difficulty on other tests of concentration, e.g. the Graded Difficulty Arithmetic test or on a test of memory ability (the RAVLT). This suggests that the cognitive difficulties associated with tinnitus are specific rather than generalised.

The proportion of tinnitus subjects reporting difficulties in concentration was higher in these studies than in some other studies (Tyler & Baker, 1983, Stephens et al., 1993). This may be because other studies have relied primarily on subjects' complaints rather than on their reports during interview; however, one of the other studies (Stephens et al., 1993) did seek to follow subjects' complaints up with interview questions. It may be that the higher prevalence of cognitive difficulties in the present studies reflects a difference in the populations studied. The subjects in the present studies were drawn from a tertiary clinic and as such may have more complex problems than subjects seen in primary or secondary clinics or in a community setting. Alternatively, it may have been due to the demand characteristics of the study. Vernon (personal communication) categorised tinnitus complaints in terms of whether they occurred "often" or "sometimes". If the two categories are combined then 72% of his sample of tinnitus patients experience cognitive difficulties. The present findings therefore do not seem exceptional. Rather they suggest that the report of cognitive difficulties was not disproportionately represented in the Tinnitus populations studied in this thesis. It is interesting, and unexpected, that in the present research reports of difficulties in cognitive functioning were also made by a high proportion of the Control group.

In order to further the idea that tinnitus has an effect on cognitive functioning some thought needs to be given to the psychological mechanisms through which this might happen. It is therefore necessary to discuss some of the processes involved in attention. The concept of attention can refer to the selection of information; the choice of which stimuli are important and to be responded to. It may also refer to intensive concentration on a task so as to maximise the efficiency of processing. While often poorly articulated, it is just such difficulties that many tinnitus patients complain about. The data gathered in this thesis point to the disruption of attention/concentration and information processing ability. While little attention has been given to other cognitive functions that might be involved, the findings do seem to be in keeping with the clinical complaints of tinnitus patients.

It has long been assumed that short term memory is an integral component of an information processing system. Several hypotheses have been put forward in attempts to more carefully describe the nature of short term memory. In this context, Baddeley's (1986) model of Working Memory has been one of the most influential concepts in recent times. In essence working memory is a system that allows "several pieces of information to be held in mind at the same time and interrelated" (Baddeley, 1986). The system has a finite capacity and it is possible that tinnitus might act in a way that occupies part of that capacity. Baddeley (1986) suggests that working memory consists of three major components. These are a central executive that controls the overall functioning of the system and two slave systems: an articulatory loop and a visuo-spatial scratch pad both of which help to maintain information until it is passed on to be manipulated by later systems.

Most of the research effort in the field of working memory has gone in to describing the articulatory loop. This is thought to briefly store and rehearse verbal information. Included in this is information from non-auditory sources that is converted into an auditory code, e.g. written information. A characteristic of most models of short term memory is a reliance on speech coding of information. Most models involve a process of speech rehearsal, usually subvocally, to maintain the memory trace. Baddeley (1986) suggested that this process is performed by the articulatory loop. He suggested that there are a number of sources of evidence for the existence of the articulatory loop. These will be outlined as they help to illustrate the operation and nature of the system. The first source of evidence is the existence of the 'phonological similarity effect' which describes the tendency for subjects' errors in recall to be phonemically similar to the correct item and for sequences of items to have similar speech sounds to be harder to remember in the appropriate order. The importance of phonological coding of information for the operation of the articulatory loop has been repeatedly demonstrated (Baddeley, 1986). A second source of evidence has come from the effects of articulatory suppression. This involves preventing the subject from rehearsing material by requiring him or her to articulate repeatedly some irrelevant item such as a nonsense syllable or the word '*the*'. Suppression reduces memory span (digit span) and abolishes the phonemic similarity effect. Initial studies referred to the phonological similarity effect as acoustic, implying that the similarity of sound items is the important factor. It has subsequently been suggested that the coding is articulatory rather than acoustic. It is thought that the effect is based on the spoken similarity of the material rather than its similarity of sound. The effects of articulatory suppression supports this view. A third source of evidence about the articulatory loop came from experiments on the effect of word length on memory span. Word length has been shown to be a crucial variable in memory span; the longer the words to be remembered the fewer words contained in the memory span. This suggests a trace decay hypothesis for short term memory rather than a limited number of storage units. A memory trace will decay over time unless it is rehearsed. Representation of the information either externally or by rehearsal will help to keep the trace alive; the amount retained will therefore be a function of the rate of decay and the rate of rehearsal. With few items the subject will be able to rehearse the complete sequence in less time than it takes the memory trace to decay; with longer sequences the time needed to rehearse is greater and may exceed the decay time.

The word length effect is abolished by articulatory suppression indicating that the phonological store implied by that effect is the same as that implied by the phonological similarity effect. The model therefore used a concept of a time based loop based on articulation and consisting of articulatory programmes that feed the process of articulation that in turn prevents the articulatory programmes from fading. The phonological similarity effect was assumed to be due to confusion among articulatory programmes with items involving similar sounds also involving similar articulatory patterns. Articulatory suppression was thought to pre-empt the articulatory system, disrupting its use of short term storage. This model of working memory however did not explain all of the observations that were made; in particular it was found that the phonological similarity effect is disrupted by articulatory suppression only if the material is presented visually. When material is presented auditorially the effect remains present. The word length effect, however, continues to be abolished by articulatory suppression when information is presented auditorially.

The phonological similarity effect and the word length effect therefore reflect different components of the articulatory loop. The word length effect is thought to reflect articulatory rehearsal and is influenced by a trace decay effect. Removing the process of rehearsal is sufficient to remove this effect. The phonological similarity effect is thought to be a function of a short term store that is maintained and refreshed by the process of articulation and that can in turn be used to feed the articulatory process.

Baddeley (1986) therefore described an amended articulatory loop model. It was proposed that the revised articulatory or phonological loop consists of two components, a phonological storage system and a rehearsal loop. The phonological storage system is equivalent to an "inner ear" while the rehearsal loop is equivalent to an "inner voice". The inner voice is assumed to be the articulatory loop system requiring either sub-vocal speech or an auditory input for information to be coded. The "inner ear" is assumed to involve some form of acoustic image and is considered to be independent of articulation and can set up phonological representations. The phonological loop represents a stage in cognitive processing that can be accessed by both stimuli of external origin and internally generated images. Auditory stimuli receive obligatory access to the phonological loop and can disrupt existing behaviour (Baddeley, 1984; Salame & Baddeley, 1983).

According to Baddeley (1986) the central executive acts as a supervisor or scheduler, capable of selecting strategies and integrating information from several different sources. As such it is related to the control of attention and is responsible for allocating attentional resources. Baddeley (1986) does not describe a model for the central executive himself, but rather favours a model of the attentional control of behaviour proposed by Norman and Shallice (1980). This model assumes that most behaviours are controlled by schemata or collections of actions that are produced automatically in response to the appropriate triggers. These schemata may operate at different levels of volition from the barely conscious, e.g. brushing a fly off one's arm, to more deliberate actions such as parking a car. Several schemata may be operating at any one time. Conflict between them is avoided through the operation of an automatic conflict resolution process that selects one schemata over the others according to priorities and environmental cues. In addition to this semi-automatic conflict resolution process the model incorporates an overall controller, the supervisory attentional system (SAS). This over-rides other influences on the conflict resolution system when external factors demand it.

Baddeley (1986) suggested that Norman and Shallice's (1980) SAS is equated with the central executive. He suggested that the concept offers an explanation of some of his own observations such as those associated with asking subjects to randomly produce letters of the alphabet. Baddeley's (1986) description of this work helps to provide an illustrative example of the functioning of the SAS. When required to randomly produce letters of the alphabet at speed people begin to omit responses or to produce stereotyped sequences (e.g. ABC, XYZ). Success on the task (i.e. the amount of randomness) increases with the time allowed per response. Baddeley (1986) suggested that the retrieval process is relatively automatic but is inclined to produce increasingly stereotyped responses, i.e. something that the subject is expressly trying to avoid. In order to avoid stereotyped responses the subject must monitor prior responses and maintain a strategy. The SAS is required to over-ride the underlying schemata. The SAS is assumed to have limited capacity. At slow rates it can perform well but as the pace of processing increases the SAS will become overloaded and the underlying schematas become more influential.

The SAS is called upon under a range of circumstances including: tasks that involve planning or decision making, situations in which the automatic processes appear to be in difficulty and some form of "trouble shooting" is required, where novel or poorly learned actions are required, where the situation is dangerous or difficult and where some habitual response or temptation is involved. The SAS is therefore involved in monitoring and controlling behaviour and in planning future activities. Shallice (1982) suggested that the frontal lobes may be involved in the operation of the SAS and that the SAS offers a way of understanding the pattern of deficits associated with damage to the frontal lobes. Characteristically frontal lobe disorder involves "disturbed attention, increased distractibility, a difficulty in grasping the whole of a complicated state of affairs, an ability to work along routine lines but inability to master new tasks or new situations" (Rylander, 1939). Milder cases will show only some of these difficulties. Shallice (1982) suggested that in cases of frontal lobe disorder routine activities can carry on relatively normally on the basis of the contention scheduling processes that rely on schemata not dependent on the frontal lobes. The subject will, however, have difficulty when required to initiate new behaviour or to discontinue or modify ongoing activity. Baddeley (1986) proposed the term 'dysexecutive syndrome' to describe the collection of deficits that may be associated with dysfunction of the central executive.

Disruption of behaviour will occur if different stimuli compete for the same processing capacity in working memory. The extent to which a stimulus disrupts the task in hand will presumably be determined by the characteristics of the stimulus and of the task. This is likely to be as true for tinnitus as for any other stimulus. Important characteristics of any task are its complexity and accordingly the amount of attentional space that it demands, and the modality within which it operates. It is likely that the extent to which tinnitus will disrupt the performance of a task will depend on the extent that the two compete for the same processing resources. Each of the sub-systems within the working memory system is assumed to have limited capacity. A central question, then, concerns which element(s) of the working memory system might be implicated in the cognitive difficulties that tinnitus and hearing impaired subjects suffer from.

Some guidance might be derived from research on the effects of external noise on cognitive functioning. The effects of external noise on cognitive functioning seem complex. Noise can improve performance of simple, repetitive tasks, especially if the person is sleepy or unmotivated (Broadbent, 1979). It can, however, worsen performance on complex intellectual tasks and fewer accidents happen when noise levels are reduced (Broadbent, 1979). Poulton (1977) suggested that the detrimental effects of external noise could be explained either by the masking of acoustic cues or by the masking of inner speech. In support of the latter idea Smith (1991) stated that subjects undergoing the Bakan task, a cognitive vigilance tests involving the detection of sequences of digits, report that they actually say the digits to themselves. Jones, Smith and Broadbent (1979) carried out four experiments using slightly different versions of the Bakan task. In each case a detrimental effect of noise was observed but the nature of the noise effect was dependent on the specific features of the task. They also found that noise had no differential effects on digits that were rehearsed together and those that were rehearsed separately. Smith (1991) suggested that these findings argue against the idea that noise produces its effects solely by interfering with sub-vocal articulation. Broadbent (1979) also reviewed the effects of noise on the five choice serial reaction time task; he concluded that noise increases momentary inefficiency but this effect is dependent on the noise being over 95 dB and the subject being in the noise for at least a half an hour. Smith and Miles (1985) also found a detrimental effect of noise of the five choice serial reaction time task and again reported that the effects were dependent on the length of time that the subjects had been in the noise.

Hockey and Hamilton (1970) demonstrated that noise aids intentional recall but impairs incidental recall. Smith (1982) found a similar effect using priority task instructions. This suggests the mediating influence of the central executive. Other workers (e.g. Forster & Grieson, 1978) however, were unable to replicate these findings. Smith (1982) suggested that noise biases the allocation of effort towards the most rewarding behaviours or the highest priority task, but that this is dependent on factors such as the difficulty of the task. Smith (1991) suggested that the effects of noise on cognitive functioning can be eliminated by the subject adopting a different strategy for performing the task. He suggested that subjects find new ways of carrying out tasks and in so doing "adapt" to noise. This may explain why there have been inconsistent findings in this area. Smith (1990) reported that the effects of noise depended on the nature of the task; when the requirements were to monitor tasks involving active strategies then noise has a detrimental effect whereas tasks performed passively were unimpaired. Rabbitt (1979) suggested that the effects of noise on the five choice serial reaction time task (an increase in errors) can be explained in terms of noise producing inefficient control of the processes that monitor and alter performance. These conclusions point to the importance of the central executive.

Cohen, Glass and Singer (1973) found that normally hearing children who lived in noisy apartments had greater difficulty deciding whether word pairs were the same or similar sounding than children living in the same apartment block but in less noisy flats. The children from the noisy apartments also had poorer reading ability. Suter (1991) reported similar findings; school children whose classrooms looked out on to railway lines performed less well in reading tests than similar children in classrooms on the quiet side of the school. The ability to encode sound into an internal representation and to establish a relationship between the sound of a word and its orthographical representation is central to the reading process.

Baddeley (1986) described a series of "informal" experiments that demonstrate the decremental influence of noise on digit recall. Unattended speech was found to have a greater effect than white noise on digit recall suggesting that the effect was due to the meaningfulness of the noise rather than just to the influence of the orienting reflex.

It should be noted, however, that white noise did also have a decremental effect on recall. Baddeley (1986) did not seek to account for this. It could have been because the subjects attributed some significance to the noise or because there is also an effect due to an attentional disruption. Salame and Baddeley (1982) went on to carry out an experiment examining the effects of articulatory suppression and unattended speech on memory for visually presented digits. Their results suggest that unattended speech impairs performance by corrupting the phonological store not by serving as a general distracter. In a later study Salame and Baddeley (1983) examined the effects of unattended white noise with that of Arabic speech at 75 and at 90 dB. They found the same disruptive effect of speech at both intensities but no effect due to noise. This suggests that the intensity of noise is not the crucial factor in this effect.

The evidence from the literature on the effect of noise on cognitive processing is therefore mixed. The conclusions from some studies point to the critical role of the central executive in mediating the effects of noise. The overall conclusions from the more recent work of Baddeley and colleagues, however, highlight the importance of disruption of the phonological loop in bringing about the effects of noise. The studies carried out by this group have the merit of being formulated within the context of the working memory model. In essence, they take thinking about the effects of noise back in the direction of the early hypothesis put forward by Poulton (1977) that it has its effects though interference with internal speech.

Thought needs to be given to the neuropsychological processes involved in the tasks that the subjects in this thesis found difficult, and to the nature of tinnitus. The perception of tinnitus involves the processing of information that is not external to the overall system but that is not wholly of central origin, i.e. it is not imagined or a memory. The phonological loop may therefore be particularly relevant to the experience of tinnitus. The habituation model of tinnitus, however, suggests that tinnitus distress is the result of a continuing orienting reaction; this would implicate the central executive.

When considering the neuropsychological processes involved in the tests used in this thesis it is important to remember that subjects' performance on the letter cancellation and Verbal Fluency tests followed opposite courses, i.e. the significant difference between groups on the letter cancellation test was reduced to a non-significant trend when hearing loss and Trait anxiety were controlled for while in the case of Verbal Fluency a non-significant trend became a significant difference between groups when hearing loss was controlled for. Both of these tests assessed concentration and both are thought to reflect frontal lobe functioning. However, some consideration needs to be given to the differences between the tasks involved. The Verbal Fluency task is much more clearly a test of verbal information processing than is the letter cancellation task. Another important difference is that the letter cancellation test involves searching the external environment for a particular target while the Verbal Fluency test involves a search of the subject's internal memory structures. The Verbal Fluency test also involves the manipulation of information, e.g. words must be categorised according to initial letter and according to whether they are proper nouns or not and whether they have already been said or not. The information manipulation involved in letter cancellation is much less extensive involving primarily template matching. It is likely that the Verbal Fluency task involves not only a search of phonological representations of words but also of orthographical representation. It is accepted that this happens in some other tests of concentration such as digit span (Lezak, 1983).

The cognitive neuropsychological processes involved in the Verbal Fluency test must, at present, be speculated on; there is no published systematic evaluation and description of these processes. While the characteristics of the Verbal Fluency test would point to the involvement of the central executive, the task also must clearly involve operations of both parts of the phonological loop. Prior to being spoken, words must be drawn in to the phonological loop or "inner ear" either from a memory set of similar sounds or from some set of orthographic representations. They will then be rehearsed in the articulatory loop prior to being spoken. It is highly likely therefore that the process involves the interface between that system and an "inner eye" in which the words are represented orthographically.

In order to avoid the habitual response of reading, the STROOP test must also involve the operations of the central executive. The tendency to read the words points to the involvement of the phonological loop. It is also almost certainly the case that most subjects sub-vocally say the word on the STROOP colour-word task, as well as articulating the name of the ink in which each word is printed. In order for colours to be named the "inner eye" must again be involved. The deficits observed on the Verbal Fluency and the STROOP task would seem to involve the several parts of the working memory system.

The CFQ results ostensibly also point to the involvement of the central executive in the difficulties that tinnitus (and to some extent deafened subjects) manifest. There is a clear parallel between the "loss of overall control" that Broadbent et al. (1982) suggest is implicated in a high CFQ score and the dysexecutive syndrome that Baddeley (1986) refers to when discussing the dysfunction of the central executive. The difficulties referred to in the CFQ are often in over-learned or automatic behaviours. This is in keeping with the findings of Hockey and Hamilton (1970) of improved intentional recall but impaired incidental recall in noise. The information processing stage involved is therefore more likely to be at the level of the central executive. It is conceivable that the ability of the central executive to maintain behaviour in pursuit of a particular goal is interrupted by the demands of the tinnitus as a competing stimulus - with the result that the orienting response to tinnitus is elicited. The fact that Tinnitus subjects (and to an important extent non-tinnitus, hearing impaired subjects) report the types of slips of actions referred to in the CFQ suggests that tinnitus may have an impact when the demands of other tasks are not great. In some way the minimal demands of other tasks offer tinnitus the "opportunity" to occupy attentional capacity. The CFQ data from the present studies may offer some support for this idea.

The findings from the Cognitive Failures Questionnaire, however, require very careful interpretation. A high CFQ score may reflect subjects forgetting whether or not things have been done correctly as much as the making of actual mistakes. As such it reflects a failure to input information in to memory; it is possible that the difficulty comes at the encoding of the information at one or other of the working memory stages, and not necessarily at the central executive level. If the deficit associated with a high CFQ score is to do with defective encoding of information then the difficulty would lie in the phonological loop and/or its interface with another system, e.g. the "inner eye".

One possibility is that tinnitus might have a greater disruptive effect on more demanding tasks; such tasks require more attentional resources that may be consumed by processing tinnitus information. The data from these studies do not lend strong support to this idea. There was no clear tendency for tinnitus subjects to perform more poorly on more demanding tasks. The PASAT is one of the most demanding neuropsychological tests in common use and both Tinnitus and Control subjects performed equally well on it and in line with the published mean score.

The findings from the PASAT make an important contribution to the overall picture. The fact that neither Tinnitus nor Control subjects exhibited a deficit on this test is important. Success on the PASAT must involve the smooth operation of the central executive. There is a tendency for subjects to add numbers to the previous answer on this test. This tendency must be resisted; the previous answer must be disregarded and attention directed at the next number while retaining the previous number. This selection or allocation of attention is a central executive function. The fact that both groups in Study Six did well on this test suggests that the blanket inclusion of the central executive in explaining cognitive difficulties associated with tinnitus or hearing loss may be too crude.

The importance of the slave systems of the working memory system in hearing loss is pointed to by Lyxell, Ronnberg and Samuelsson (1994) who suggest that inner speech may be important in lip-reading. Both reading and lip-reading involve a recoding of visual stimuli into an auditory (inner speech) format. They compared the internal speech functioning of deafened and normally hearing adults using rhyme judgement tasks and lexical access tasks. They reported no differences between the groups in terms of speed or accuracy when phonological processing was not a prominent task demand. Their findings, however, indicated that deafened subjects did significantly worse (in terms of accuracy of judgement) when phonological processing became more prominent in the rhyme judgement tasks. In particular, deafened subjects were less able to judge whether word pairs rhymed when presented with word pairs that were orthographically similar but did not in fact rhyme. Accuracy on the tasks was correlated with the duration of the hearing loss. They concluded that the mechanical aspects for search and access of verbal information in semantic long term memory remains intact but that the representational aspects of internal speech deteriorate over time as a consequence of acquired hearing loss. They suggested that deafened subjects are less capable of forming internal phonological representations to use these for matching of visual input but that this difficulty is revealed only when the subject is asked directly to make phonologically based decisions to solve a task. They suggested that a consequence of this deterioration may be worsened performance on any cognitive tasks that require a direct usage of inner speech such as reading or thinking.

The distinctions between the processes involved in the STROOP test and the PASAT or between the Verbal Fluency test and, say, the Graded Difficulty Arithmetic test (in Study Four both groups achievements were in keeping with the published norms on the latter test), are more likely to lie in the nature of the information being manipulated and therefore in the realms of the slave systems of working memory. This is in keeping with the Baddeley's and Poulton's ideas about the effects of external noise. Successful performance on all of these tests is dependent on a number of functional systems. There has been some debate about whether the skills of calculation are subserved by structures in the left hemisphere or whether right hemisphere structures are also involved (Troup, Bradshaw & Nettleton, 1982; Grafman, Passafiume, Faglioni & Boller 1982). Both types of task involve inner speech and so difficulty on one and not the other implies that attributing the problem to disrupted inner speech needs to be qualified.

The cognitive processing of whole words and possibly of reading is clearly greater in the Verbal Fluency and STROOP tests than in the arithmetical tests. Attributing the difficulties in cognitive functioning experienced by tinnitus and hearing impaired patients to this process would be in line with the work of Lyxell, et al. (1994) that hearing loss leads to poorer ability to form internal phonological representations that can be matched to visual input. It is also in keeping with the observations of Cohen et al. (1973) and Suter (1991) that exposure to noise is associated with poorer reading ability in children. The findings of this thesis, however, suggest that tinnitus does have a disruptive effect on cognitive functioning in addition to that which may be attributed to hearing loss. In order to determine whether the disruptive effects of the two symptoms can be attributed to the same or different processes will need further and more refined cognitive testing.

While this thesis was being written further data have emerged pointing to the involvement of central factors in tinnitus perception. Jacobson, Calder, Newman, Wharton and Ahmad (1995) investigated whether the selective auditory attention abilities of subjects with troublesome tinnitus differed from those of normal subjects and they used negative difference wave (Nd) as an electrophysiological index of early selective auditory attention and they reported that this was of significantly greater magnitude in the tinnitus subjects. They speculated that the process of selective auditory attention, which is initiated at prefrontal sites, affects auditory processing at a subcortical level. They suggested that the tinnitus subjects were making a more thorough comparison of the physical characteristics of each auditory signal than were the control subjects. The work gives rise to the implication that there are differences in information processing in tinnitus patients.

Jacobson et al. (1995) also found that the N1 component occurred significantly later in the presence of selective attention in tinnitus subjects only. This is in contrast to Hoke et al.'s (1989) findings using N1 and represents a challenge for interpretation.

Cacace, Cousins, Moonen et al. (1996) used functional magnetic resonance (*f*MRI) to assess tinnitus related activity. They assessed three subjects with an unusual form of tinnitus that was evoked by eye gaze. One subject experienced tinnitus that was evoked by cutaneous stimulation. All had undergone neurosurgery for the removal of space occupying lesions of the posterior fossa and all lost hearing in the operated ear following surgery. The subjects had the ability to turn their tinnitus on and off at will and therefore represented good subjects for *f*MRI. Two control subjects were examined; these had undergone similar surgery and lost their hearing in the affected ear but did not develop tinnitus. Cacace et al. (1996) reported significant activation in one of their three subjects with eye gaze evoked tinnitus. In that subject, tinnitus related activity was detected in several CNS locations in the upper brainstem and frontal cortex. However, as these researchers pointed out eye gaze evoked tinnitus is distinctly different from other forms of tinnitus and there may be difficulties in generalising from these data to a wider population of tinnitus patients. Furthermore, the effect was observed in only one of their three tinnitus subjects.

Lockwood, Salvi and Coad (1996) examined five subjects with unilateral tinnitus and three controls using positron emission tomography (PET) scanning. They reported that tinnitus was associated with increased cerebral blood flow associated in the middle temporal gyrus, the hippocampal and fusiform gyrus, the medial geniculates and the limbic system.

The evidence for central processing of tinnitus stimuli therefore continues to grow, although as yet in a somewhat piecemeal and inconsistent fashion. The data gathered in Studies Four, Five and Six of this thesis add to this literature. They do so by revealing slower information processing ability in patients with tinnitus in a way that points to differences in their frontal lobe functioning.

Chapter 11

Summary and General Discussion

The findings of this thesis add to the body of knowledge concerning psychology and audiological medicine in a number of ways.

Emotional Consequences of Audiological Symptoms.

1. The Emotional consequences of tinnitus and hearing loss.

The results of Study One indicated that there was a high prevalence of psychological disturbance among neuro-otology patients; on the basis of a structured interview carried out by a psychologist, forty-two percent of these patients were rated as in need of psychological help. It was noted that the symptom of dizziness was associated with the highest prevalence (64%) of psychological disorder. The prevalence of psychological disorder among tinnitus patients was 45%, and among patients whose main complaint was hearing loss it was 27%. The finding that 27% of patients with a main complaint of hearing impairment were in need of psychological help is broadly in keeping with Erikson-Mangold's (1991) finding that 23% of hearing impaired subjects had SCL-90 scores comparable to those of psychiatric out-patients. The SCL-90 scores of the cochlear implant control subjects in Study Three of this thesis add weight to the idea that hearing loss can have an important and deleterious psychological impact.

There was good agreement between the judgments derived from the structured interview and the classification of patients based on GHQ scores suggesting that this instrument is useful in an audiological medicine clinic. Concerns that the use of the questionnaire might lead to mis-classification of patients and so be inappropriate in this setting were unfounded. The use of the SCL-90 in Study Three, however, was not so straightforward. It proved helpful in identifying some highly unusual cochlear implant candidates; however it did so by technically mis-classifying four out of five of them. These candidates were dissimulating when completing the questionnaire. Dissimulation is something that has not been reported in this context previously and the finding sounds a cautionary note about the use of such questionnaires in decision making regarding cochlear implant surgery.

2. The psychological effects of cochlear implantation.

The psychological impact of hearing loss is further evidenced by the findings of Study Two. The provision of a cochlear implant led to clear improvements in the psychological well-being of eight out of ten patients indicating that the restoration of some acoustical input was of great importance to these subjects. The implants used by the subjects in that study were single channel, extra-cochlear, implants that have been associated more with improvements in perception of background sounds than with large improvements in communication ability (McKenna, 1986). This points to the importance of hearing at a fundamental level rather than just because of its function at a linguistic level, in line with Ramsdell's (1962) suggestions.

Eriksson-Mangold (1991) reported that depressive symptoms in hearing impaired patients did not correlate with their experience of hearing disability or handicap. She argued that one explanation for this might lie in the fundamental importance of non-verbal sounds for psychological well-being (but see below). It should be noted, however, that not all ten subjects in Study Two reported improvements in psychological well-being. This parallels the findings of Knutson, Hinrichs, Tyler, Gantz, Sanchez and Woodworth (1991) and argues against a model of hearing that focuses on a threshold effect and in favour of one that also implicates people's expectations and life experiences.

The findings of Study Two are also in line with the findings of the Institute of Hearing Research's evaluation of cochlear implantation in the United Kingdom (Summerfield & Marshall, 1995). That study reported improvements in factors such as depression and quality of life after cochlear implantation and indicated that greater gains were reported by those who were using multi-channel rather than single channel devices.

In examining the psychological effects of the restoration of hearing, Study Two offered a perspective that had hitherto rarely been available. There were, however, a number of methodological weaknesses. It was a purely retrospective assessment of the subjects' perceptions of change. As such it did not assess objectively measurable changes in behaviour, nor did it assess the beliefs of significant others about the implant users; both of these would represent sources of strong corroborative evidence for the changes reported in the study. Care should also be taken when drawing inferences from a small subject group.

3. The importance of multiple symptoms.

The higher prevalence of psychological disturbance among patients complaining of dizziness than among those complaining of tinnitus or hearing loss suggests that different levels of emotional disorder are associated with the differing nature of the symptoms. In her studies of hearing impaired people, Eriksson-Mangold (1991) emphasised the role of hearing loss per se in bringing about emotional distress; she identified a group of subjects who were psychologically disturbed and who had few stresses apart from the hearing loss. However, she also identified a group of subjects who had less hearing disability but a range of other stresses and elevated levels of psychological distress. The psychological disturbance identified in Study One of this thesis was associated with having received previous psychiatric help and also with the number of symptoms that patients complained of. This might suggest that the association of emotional disturbance with one or another symptom, such as hearing loss or tinnitus may be overly simplistic. The present findings could be interpreted as in keeping with those of Jones et al. (1984) who reported that when other health problems are controlled for the correlations between hearing loss and anxiety and depression are found to be weak.

Eriksson-Mangold (1991) reported that depressive symptoms among hearing impaired patients correlated with age and with the presence of tinnitus. This again raises the possibility that distress is associated with multiple symptomatology or poor overall health. Andersson et al.' s (1995) finding that health factors and hearing loss and psychological factors clustered together adds further support to the importance of overall health rather than specific symptoms in determining psychological well-being. Given that psychological distress is associated with so many disparate medical symptoms this seems an intuitively appealing conclusion. The repeated finding in this thesis of higher levels of distress among tinnitus subjects than among subjects complaining of hearing loss does not necessarily contradict this view. Many of the tinnitus subjects studied also had a hearing loss whereas at least in Studies Four, Five and Six, the hearing impaired subjects did not have tinnitus.

The possible complication of the influence of multiple symptoms or general health factors may help in understanding the lack of a clear relationship between the intensity of audiological symptoms and the degree of psychological distress that has often been reported. In this thesis, however, some relationship between the degree of hearing loss and psychological disturbance was found. In Studies Four and Six significant correlations were found between hearing loss and Trait anxiety scores. This relationship was not found in Study Five nor was there any relationship between hearing loss and State anxiety or depression. It seems unlikely therefore from these data that there is a relationship between the extent of hearing loss and psychological distress in some general sense. It should be noted however that subjects with more severe hearing loss were deliberately excluded from Studies Four, Five and Six and the data from those studies need to be interpreted with that exclusion in mind.

4. The importance of personality factors.

The relationship between hearing loss and Trait anxiety requires some explanation. The possibility that hearing loss leads to changes in personality seems a more parsimonious explanation of this relationship than the idea that those with Trait anxiety go on to develop poorer hearing.

The suggestion that tinnitus patients suffer from elevated levels of psychological distress is apparent from the findings of Study One and from the STAI scores in Studies Four, Five and Six. In the case of tinnitus patients, this distress is particularly evident in the Trait anxiety scores in the latter studies. In each of those studies the Tinnitus groups' Trait anxiety score was in the higher part (i.e. more pathological) of the distribution of scores for undergraduates and closer to the center of the distributions of scores for general medical and surgical, and neuropsychiatric patients (Speilberger et al., 1970). The findings of Study Five also pointed to high levels of State anxiety in tinnitus patients; the mean score was in the upper part of the distribution for undergraduates but in the lower half of the distribution for general medical and neuropsychiatric patients. The Tinnitus groups' State anxiety scores in the other studies were closer to the center of the distribution for undergraduates (even though State anxiety distinguished the groups in Study Six). Overall, the picture is one of elevated Trait anxiety scores in tinnitus patients suggesting that their distress can be understood in terms of a longer standing personality trait rather than just a short term reaction to circumstances. Psychological disturbance was not such a strong feature of the hearing impaired Control groups in Studies Four, Five and Six. The State and Trait anxiety scores for these groups were also close to the center of the distribution of scores for undergraduates although they did overlap with the scores for general medical and neuropsychiatric patients. A number of the hearing impaired Control subjects in each study did, however, obtain high STAI scores.

The idea that Trait anxiety, rather than State anxiety, should be a clearer characteristic of tinnitus patients is interesting. It might be argued that the presence of tinnitus in people with elevated Trait anxiety would lead them also to have elevated State anxiety scores. This was found only in Study Five. Other researchers (e.g. Gerber, Nehemkis, Charter & Jones, 1985; Reich & Johnson, 1984) have provided some evidence for 'psychopathological' elements in the personality of tinnitus patients, however, this evidence has not been unequivocal. For example, the distinguishing feature of Collet et al.'s (1990) investigation of the MMPI profiles of tinnitus patients was of normal scores on all of the scales except for depression.

Having studied hearing impaired patients Eriksson-Mangold (1991) argued that the SCL-90 may be measuring a personality trait, rather than only emotional state, in hearing impaired patients; she found that SCL-90 scores correlated with subjects experience of handicap four and a half years later. She suggested that this personality trait might be resistant to the effects of rehabilitation.

Interestingly, depression was not a feature of either the Tinnitus or hearing impaired Control groups in Study Six. Hinchcliffe and King (1992) suggested that depression is the principal distinguishing feature between tinnitus complainers and non-complainers. As the subjects studied in this thesis were all attending hospital clinics for help with tinnitus (and hearing loss) it may be assumed that they represented a group of complainers rather than non-complainers. The present findings are more in keeping with those of Kirsch et al (1989) who reported BDI scores in the normal range for tinnitus patients. Similarily, Wilson et al. (1991) and Andersson (unpublished) refer to only 'mild' depression among tinnitus patients. The current findings do not lend support to Erlandsson's (1990) suggestion that tinnitus patients may be divided into those who manifest a depressive type reaction and those who experience anxiety. An increased occurrence of depression in the hearing impaired has been documented (Gilhome-Herbst & Humphrey, 1980; Knapp, 1948; Thomas, 1984). The present findings are at odds with these others. Nonetheless, it might be expected that both hearing loss and tinnitus would lead to depressive reactions. Both symptoms result in a loss of sensory acuity and also in a loss of control in a variety of circumstances. The present findings suffer from the disadvantage that depression was specifically assessed in only one study. The data from Study One do not contribute to this aspect of the debate. The GHQ measures primarily "general psychological distress" although it purports to offer more definite classifications, the factor structure of the questionnaire indicates that these classifications each reflect a very small amount of the variance within the instrument. Clearly, the present findings highlighting the importance of Trait anxiety in tinnitus patients need to be replicated.

The data in this thesis, in common with many of the other studies referred to, suffers from the disadvantage that they were obtained from populations of subjects attending hospital clinics. These groups are not representative of the wider population of people with hearing loss and/or tinnitus. They represent a sub-group that is seeking help and is therefore likely to be more psychologically distressed than the larger population.

Cognitive functioning in people with tinnitus and with hearing loss.

1. Information processing and tinnitus.

The idea that tinnitus patients have particular traits that render them vulnerable is supported by the CFQ scores from Studies Four, Five and Six. The results of these studies suggest that there is a relationship between the CFQ and Trait anxiety but that the CFQ was measuring a distinct characteristic. Broadbent et al. (1982) suggested that this characteristic represents a vulnerability to cognitive failure. This finding provides support for the tinnitus patients' complaints of concentration problems. The findings from Studies Four, Five and Six also provide more direct neuropsychological evidence of difficulties in concentration and information processing in tinnitus patients. This is the first time that such evidence has been obtained. The data from these studies point to slower frontal lobe functioning in tinnitus patients.

A number of the neuropsychological tests used in Studies Four, Five and Six (e.g. the Digit Symbol Substitution test, the Graded Difficulty Arithmetic test, the PASAT) did not distinguish the Tinnitus and hearing loss Control groups. Some of the non-significant differences may be attributable to the choice of control group. The hearing impaired Controls may have performed less well than, say, a normal control group and hence with the result that the differences between that group and the Tinnitus group was smaller than required for significance. It is difficult to compare some of the test results (e.g. the Digit Symbol Substitution test, the RAVLT) with published norms as the latter tend to be stratified by age and this would lead to the populations in the current research being divided into very small groups. The choice of groups, however, was clearly not the only reason for all of the non-significant findings; in Study Six both groups achieved scores on the PASAT that were in keeping with published norms.

It is possible that multiple testing led to some significant differences by chance. However, the findings from Study Four concerning Letter Cancellation and Verbal Fluency were replicated in Study Five. It was also the case that the significant difference in CFQ scores found in Study Four was observed again in Study Five. Another possibility is that the use of different tests led to different results because the tests assess slightly different functions and reflect the operation of different cortical systems. The frontal lobes account for one third of the brain and it is not uncommon, in a clinical neuropsychological setting, to observe a deficit on one test of frontal lobe function and not on another.

The findings do not exclude the involvement of other parts of the brain in tinnitus perception. Only one test (the Rey Auditory Verbal Learning Test) was used to assess cognitive processes other than concentration or information processing and therefore the involvement of other brain structures. There would be a value in investigating the abilities of tinnitus patients in other areas of cognitive functioning.

The present findings are in keeping with the neurophysiological model of tinnitus perception put forward by Jastreboff (1990) and are in line with recent neurophysiological studies (e.g. Attias et al., 1993; Shiraishe et al., 1991; Cacace et al., 1996; Lockwood et al., 1996) that point to the involvement of central processing in tinnitus perception. The present findings of deficits on neuropsychological tests of concentration/information processing abilities reflecting frontal lobe dysfunction provide a different but complementary form of evidence. The sizes of the groups in the present studies of cognitive functioning were relatively small. However, they were larger than those in most of the neurophysiological studies quoted and the fact that impairment of cognitive functioning was apparent in small groups adds weight to the results. The finding of disrupted cognitive functioning in tinnitus patients indicates that more consideration needs to be given to this difficulty in any future attempts to describe tinnitus complaint.

2. Information processing in hearing impaired subjects.

The data from Studies Four, Five and Six provide evidence for a deficit in information processing in deafened subjects as well as tinnitus subjects. On the one hand, this suggests that the choice of a hearing impaired control group was inappropriate; the cognitive deficits experienced by tinnitus patients might have been more clearly revealed had a normal control group been used. On the other hand, this finding was somewhat unexpected and interesting. The cognitive status of elderly hearing impaired people has been a focus for study, and hearing impairment has been associated with dementia but conflicting results have been reported. For example, Slater and Roth (1969) described two thirds of patients with organic brain syndrome as having a "hearing impairment". They state that the association is too strong to be wholly explained by the advanced age of the subjects. Gilhome-Herbst and Humphrey (1980), however, reported that a significant correlation between degree of hearing loss and degree of cognitive impairment disappeared when the effects of age were controlled for which suggests that the association between hearing impairment and cognitive deficit may be due to age alone. Eastwood, Corbin, Reed, Nobbs and Kedward (1985) found that there was no clear relationship between hearing loss and organic brain syndrome in a group of elderly residents of a nursing home. From a review of the literature, Jones and White (1990) concluded that the findings relating to deterioration in cognitive functioning were unclear, especially in studies that controlled for age. The studies of cognitive functioning in this thesis are, however, distinct from those in the literature on two important points. Firstly, the studies of cognitive functioning in hearing impaired people referred to in the literature are concerned with groups of elderly people. The series of investigations of cognitive functioning in this thesis deliberately excluded elderly people and focused on subjects between the ages of eighteen and sixty. The present findings are therefore unlikely to be confounded by coincidental senile dementia. It is worth reiterating that all of the subjects who did poorly on the STROOP in Study Six were aged forty-nine years or less. The present set of studies also used tests of concentration that are commonly employed by neuropsychologists rather than brief "thumb nail" assessments of the sort referred to in the literature, e.g. the Mini Mental State Examination used by Eastwood et al. (1985).

3. Cognitive processing: Mechanisms.

The data from Studies Four, Five and Six indicate that hearing impaired subjects perform poorly on many of the same tests that present difficulties to tinnitus subjects but to a lesser extent than the tinnitus subjects. These data suggest that the cognitive difficulties experienced by hearing impaired people are of the same nature but less severe than those experienced by tinnitus patients, However, a more refined investigation of the similarities and differences between tinnitus and hearing impaired subjects in this respect represents a focus for future research.

As discussed in Chapter 10, the difficulties experienced by tinnitus patients may reflect disruption in the central executive of the working memory system (Baddeley, 1986). However, the data also point to a deficit at the level of the slave systems of working memory. This conclusion must be somewhat speculative as the tests used in these studies were not sufficiently refined to clearly demonstrate the influence of one part of the working memory system to the total exclusion of other parts. It would now be profitable to pursue the issue through the use of test procedures such as those described by Baddeley (1986) for the specific study of the working memory system.

The present studies of cognitive functioning (and in particular Study Six) indicate that the cognitive dysfunction is present in only some tinnitus and hearing impaired subjects. The epidemiological evidence regarding tinnitus (e.g. Davis, 1989; Axelsson & Ringdahl, 1989) also indicates that not all people who experience tinnitus are distressed by it. The findings of Study One of this thesis also show that many more people experience hearing loss and tinnitus than have psychological disturbance associated with these symptoms.

A loss of control is implicit in the experience of impaired cognitive functioning. Deficits of information processing, such as those pointed to in the present studies, will result in the person being less well able to deal with the demands of everyday life in just the manner that is indicated by the Cognitive Failures Questionnaire. Loss of control is also one of the most common features of the clinical complaints of tinnitus patients and is highlighted in studies of tinnitus complaint such as that of Scott, Lindberg, Melin, and Lytkens (1990) who showed that the report of difficulties in concentration was one factor that predicted tinnitus distress. Eriksson-Mangold (1991) emphasised loss of control (in one form or another) when seeking to account for the adverse emotional effects of hearing impairment. Emotional disturbance is certainly a common feature of people who have impaired cognitive functioning as a result of neurological damage (Lezak, 1983; Lishman, 1987). Unfortunately, in the present studies of cognitive functioning no attempt was made to distinguish between those Tinnitus subjects who were "tinnitus complainers" and those who had simply reported the symptom. It would be of great interest to see whether tinnitus complainers do less well on tests of cognitive functioning than those who only report it when asked. There was no association between subjects' complaints about tinnitus as assessed by the short TQ and their performance on the neuropsychological tests. However, this is likely to be because the short TQ makes only one reference to cognitive difficulties; future studies should use the full TQ. The possible link between tinnitus complaint and cognitive functioning provides an important focus for future research. A parallel question may be asked about hearing impaired people.

The findings of Lyxell, et al. (1994) that the performance of deafened subjects on rhyme judgment tasks negatively correlated with the duration of hearing loss suggests that hearing impairment causes the change in cognitive processing. Further evidence for the idea that audiological disorder precede psychological changes that are relevant to cognitive functioning comes from Cooper et al. (1974). These authors compared duration of hearing loss in consecutively hospitalised paranoid patients with those suffering affective disorders. They found that the paranoid group had a significantly greater percentage of subjects who had a long standing hearing loss prior to their psychiatric illness. Impaired cognitive functioning, and particularly impaired frontal lobe functioning, has been implicated in schizophrenic type disorders (Frith, 1995). This suggests that the hearing loss may precede the cognitive difficulties. This would be in keeping with the typical clinical complaint that tinnitus patients make of "I can't concentrate as well as I used to before the tinnitus". The finding that level of hearing loss correlated with Trait anxiety scores might also support this idea assuming that people develop Trait anxiety as a consequence of long term hearing impairment. Any change in cognitive processing that might be associated with audiological disorder would, in the long run, understandably lead to increased Trait anxiety.

An alternative scenario, however, might be inferred from the present findings. The point that the CFQ also reflects a long term characteristic may be reiterated in this context. In Studies Five and Six the Control groups, who performed better on some neuropsychological tests, had their symptoms for significantly longer periods of time than the Tinnitus groups who performed more poorly on those tests. It is interesting to speculate that the symptoms of tinnitus and hearing loss may have a greater impact on those who already have inefficiencies or inaccuracies in information processing, i.e. stress has greater effects on those who can not cope cognitively.

The link between cognitive dysfunction and tinnitus or hearing loss in some subjects may add weight to the categorisation of patients that Eriksson-Mangold (1991) referred to, i.e. one group of subjects who are generally stressed and may have little disability due to their auditory symptoms and another group who have fewer other stresses but experience considerable disability due to their auditory disorder. This division helps to make sense of the findings in Study One that psychological disorder is associated with particular symptoms (including more with tinnitus than with hearing loss) as well as with the number of symptoms that subjects experienced.

It is possibile that Trait anxiety is related to tinnitus complaint and that those who go on to be "complainers" are those who are predisposed to react anxiously to life events. A link between Trait anxiety and cognitive functioning is evident from the association between Trait anxiety and the CFQ in Studies Four, Five and Six. However, the link between Trait anxiety and the neuropsychological test scores was not so strong and controlling for anxiety did not remove the differences in cognitive functioning between the tinnitus and Control groups except in the case of the letter cancellation test in Studies Four and Five. It is, nonetheless, possible that Trait anxiety might come about through long standing cognitive difficulties.

The cause and effect relationships between the symptoms of tinnitus and hearing loss and those of difficulties in cognitive processing and of Trait anxiety certainly merit further investigation.

Implications for treatment.

The present findings may have implications for existing models of tinnitus and for approaches to its management. The treatment approach that is implicit in the habituation model of tinnitus proposed by Hallam et al. (1984) focuses on the reduction of autonomic arousal through the use of procedures such as relaxation and on a change in the emotional connotations of the tinnitus through cognitive therapy. A number of studies have been carried out to evaluate the efficacy of cognitive behavioural treatment approaches in this context. These have been reviewed by Andersson et al. (1995) who concluded that results have been varied, but that overall they have been positive but modest. Such approaches are however likely to be as good as, or better than, other approaches to tinnitus management such as masking therapy (Jakes, Hallam, McKenna & Hinchcliffe, 1992). Jastreboff and Hazell (1993) also highlight the role of "directive counselling" when discussing the clinical implications of the neurophysiological model of tinnitus (Jastreboff, 1991). In keeping with Hallam et al.'s (1984) ideas they suggest that patients' are threatened by their tinnitus, that patient's specific concerns about the tinnitus need to be identified and that they need to be persuaded that the tinnitus is a benign and harmless phenomenon. Jastreboff and Hazell (1993) suggested a second element to tinnitus management. They recommend that tinnitus patients wear noise generators designed to provide low level stable white noise. They argued that this will facilitate habituation by interfering with tinnitus perception by increasing the mean neuronal activity within the auditory system making the tinnitus related signal more difficult to detect. They have also reported positive results for their therapy approach (McKinney, Hazell & Graham, 1995). It is clear, however, that not all tinnitus patients are helped by cognitive behavioural approaches or by the McKinney et al.'s (1995) management approach.

The idea that tinnitus will become less distressing (and become imperceptible according to the Jastreboff and Hazell (1993) model) if the emotional connotations of it are removed is to place an emphasis on the role of the central executive in directing attention to it. If the slave systems are involved in tinnitus perception then the persistence of tinnitus distress, or a failure to habituate to it, may be due to reasons other than negative emotions maintaining an orienting response. It may be that those who have been least responsive to treatment approaches have been those with impaired information processing abilities. At least for those patients with impaired information processing it may be necessary to adopt an approach that takes account of the involvement of the slave systems of working memory. It is not clear at this stage what the constituents of such an approach might be. The use of noise generators suggested by Jastreboff and Hazell (1993) poses a dilemma in this context. The use of noise generators would seem to be analogous to exposing the subject to noise. It might be predicted from the literature on noise and attention that at least for some patients the use of such devices would have an impact on the working memory slave systems and that this may lead to reduced cognitive efficiency. The noise levels that are usually recommended for the use of noise generators are, however, very much lower than those used in any of the studies of the effects of noise on cognitive processing; however, so too are the levels of most tinnitus matching and masking. It may need to be recognised, as Eriksson-Mangold (1991) implied, that some patients may be resistant to rehabilitation. It is possible that the setting of modest goals, with frequent repetition and slow progress, i.e. the type of approach used in some neurological rehabilitation settings, may be needed for some patients.

Gilhome-Herbst (1983) suggested that the symptoms of hearing impairment bear many similarities to some types of mental disorders. These symptoms may encourage people to treat hearing impaired people as if their cognitive abilities were also impaired. The findings from the present thesis raises the possibility that, at least in some cases, these prejudices may be founded in reality.

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APPENDIX 1

	Below STROOP Cut Off		Above STROOP Cut Off			
	Mean	S.D.	Mean	S.D.	t	p
Age	44.26	8.16	42.26	12.39	-0.71	n.s.
Time since onset	12.96	10.86	14.08	11.93	-0.10	n.s.
Hearing Loss; Worst ear	46.20	28.78	50.19	28.85	0.26	n.s.
Hearing Loss; best ear	36.60	29.04	22.55	82.71	0.54	n.s.
NART IQ Equivalent	108.80	8.27	106.90	11.78	-0.45	n.s.
State Anxiety	36.80	11.35	37.25	11.34	0.10	n.s.
Trait Anxiety	42.30	10.31	40.35	10.12	0.10	n.s.
BDI	6.30	4.54	7.50	6.04	0.55	n.s.
CFQ	39.00	10.25	39.51	15.21	0.12	n.s.

Age, time since onset of symptoms, hearing loss, NART, STAI, BDI & CFQ scores for subjects with STROOP scores above and below the cut off point.