THE UNIVERSITY OF HULL

# The relationship between tinnitus, cognitive performance and demands on the individual

being a Thesis submitted for the Degree of Doctor of Philosophy in the University of Hull

By

James George Jackson

BSc. (University of Sheffield), MSc. (University of Hull)

July 2005

"Woman's milk, especially of a woman who has just borne male twins, mixed with the urine of a youth who has not yet arrived at puberty, removes ringing in the ears."

**Pliny the Elder (23 AD - 79 AD).**
Roman encyclopaedist, naturalist, scholar, & scientist.

## ACKNOWLEDGEMENTS

This Thesis has been the sum of four years of work, and in the writing of it, I have been helped and supported by a number of people who I would like to take the time to acknowledge. Firstly, I would like to thank my supervisors, Dr. Iain Coyne and Dr. Peter Clough for their advice and assistance. In addition, Dr. Catherine Fritz for her kind words of support. Secondly, I would like to thank my colleague David Marchant for his company in the office for four whole years! Furthermore, I would have struggled much more without the presence of my parents or the network of friends built up during my time in Hull - too many people to mention by name but I thank you all. I would also like to specifically mention the help of my friend Christian Mathers for his skills in putting together the computerized tasks in Study Two.

Finally, I would like to thank Sally for her invaluable support in these last few months.

# ABSTRACT

This Thesis attempted to first replicate the work of Andersson et al. (2000) to identify possible cognitive decrements in tinnitus sufferers. In addition, a number of trait variables were measured in comparison to a matched control group. It was discovered that the tinnitus population did not differ in terms of any trait, yet still performed worse on a number of cognitive tasks - performing as accurately, but significantly more slowly. It was thus concluded that the presence of the tinnitus interfered with cognition by consuming valuable and finite attentional resources.

A second study attempted to narrow this down further, identifying specific tasks and specific circumstances in which tinnitus sufferers performed less effectively than their non-tinnitus counterparts.

From these results, it was postulated that the relationship between tinnitus severity and cognitive performance is moderated by demand and as such, a longitudinal diary study (six weeks) was undertaken to measure (self-rated) effectiveness under a wide range of demands in real life. Moderated hierarchical regression techniques were thus able to identify situations in which mental demand levels drive the relationship between tinnitus and performance, thus supporting the hypothesis.

# TABLE OF CONTENTS

**Chapter One: Introduction**

# CHAPTER ONE

## Definition of Tinnitus

> Tinnitus - a sensation of ringing in the ears.
>
> [From the Latin verb *tinnire;* meaning "to ring" or "to tinkle like a bell"]
>
> **Oxford English Dictionary Online, May 2004. (http://dictionary.oed.com)**

Tinnitus is the medical term used to describe what has traditionally been portrayed as a subjective ringing, buzzing or hissing sound that seems to come from inside the head in the absence of corresponding external stimuli (Thomas, 1993). Tinnitus is instead generated internally by the auditory system and may be continuous or intermittent in nature, the result of false auditory sensations arising somewhere in the peripheral or central nervous system (Shulman, 1991). As such, these noises cannot be perceived by others - those afflicted often feeling misunderstood. The causes of tinnitus are varied, but can result from exposure to noise, degenerative ear disorders and as an unwanted side effect of some medications and other substances. Medical treatment is often sought, (e.g. surgery, pharmacotherapy and masking) but all such strategies have been ultimately unsuccessful in alleviating tinnitus (Davis, McKenna & Hallam, 1995). Tinnitus can be characterised into two broad types; objective and subjective. Objective tinnitus (vibratory tinnitus or pseudotinnitus) may or may not be audible to the patient but is audible to an observer by listening through a stethoscope placed on the patient's mastoid bone - which is located behind the ear. It is reported to occur in roughly 1% of tinnitus cases and is usually a result of arteriovenous malformation. If the cause can be determined, surgical treatment is often possible. However, this Thesis will concentrate on subjective tinnitus, which is only heard by the patient, is usually idiopathic, and is much more common. In both Germany and the United Kingdom, tinnitus is viewed as a real illness, a legitimate cause of suffering, and consequently as a justifiable reason for seeking medical help and even compensation (Kroener-Herwig, Biesinger, Gerhards, Goebel, Greimel & Hiller, 2000).

**Causes of Tinnitus**

Idiopathic tinnitus, as indicated by its name, has no readily identifiable cause, and can be defined as tinnitus that lasts for more than five minutes at a time and occurs not only after loud sounds. This excludes the trivial cases that many people experience briefly after exposure to loud noise/music (Davies, 1989). There is a trend of tinnitus becoming more likely with age, with the elderly population rating tinnitus as their tenth most common medical complaint (Billue, 1998). By their seventh decade, more than 10% of all adults report episodes of severe tinnitus, and more than 35% have moderate to severe hearing loss. Prevalence of tinnitus is therefore associated with age, but not necessarily occupational noise exposure. On the other hand, chronic noise exposure is seen to cause both tinnitus and hearing loss. It is a symptom of almost all forms of audiological disorder. As such, it has numerous causes and may be a result of acoustic trauma or disease. Tinnitus is not a disease but is instead considered to be a symptom. Pathologies related to tinnitus can involve damage to any of several distinct areas of the ear. In addition to this, environmental, dietary, physiological and psychological factors may also interact.

With regards to the outer ear, tinnitus can be caused by ear wax impacted on the ear canal or touching the ear drum itself. This wax, along with foreign bodies and possible swelling, can cause an increase in pressure on the ear drum. This extra pressure is then transmitted across the middle and inner ear, and a signal is passed on to be interpreted in the auditory centres of the brain as noise - or in this case, tinnitus. Other possible causes include: external tumours in the ear canal; perforation of the ear drum; and cholesteotoma (ear tumour). In the middle ear, it is damage to the ossicular chain that causes tinnitus. Inner ear pathologies are numerous, and include: Paget's disease; noise damage; congenital malformations; viral diseases; bacterial infections; cochlear otosclerosos; and atrophy. In addition to all of this, tinnitus can also originate due to conditions that are not necessarily related to the ear, including: systematic diseases that may be related to elevated cholesterol; allergies; thyroid problems; diabetes; hypertension; and hypotension. Tinnitus is also connected to a wide variety of pathological conditions (Seidman & Jacobson, 1996; Coles, 1997). For example: temperomandibular joint disorder (TMJ); obesity; stress; dietary deficiencies; and the intake of stimulants such as nicotine and caffeine (Vernon, 1998).

As such, a number of different circumstances result in tinnitus. The most frequent cochlear causes of these include: damage to hair cells through noise or oxotoxic drugs; changes in calcium ion concentrations; and disturbance of synaptic transmission (Romand, 1992; Lepage, 1995). Pathological changes can occur further along the auditory pathway - often due to insufficient insulation - resulting in a confusion of signals between adjacent fibres (Møller, Janneta & Jo, 1992). Additionally, abnormal activity in higher regions of the auditory system can contribute to the generation of the tinnitus signal. This concept forms the basis of the neurophysiological model put forward by Jastreboff (1990, 1996) and is described in greater detail later. However, whichever model of tinnitus generation is ultimately favoured, the majority of current hypotheses agree that abnormal neural activity in the auditory system is the origin of the signal, whichever way it is eventually interpreted and perceived in higher cortical centres (i.e. the auditory cortex).

**Incidence of Tinnitus**

Estimates of the number of people suffering from tinnitus at any one time vary greatly, but it is believed that somewhere between 6 - 20% of the population experiences a bothersome tinnitus at any particular time, with 1% experiencing tinnitus of such severity that it interferes with daily activity (Chung, Gannon & Mason, 1984; Coles, 1987). The number of individuals in the UK experiencing persistent and troublesome tinnitus is considerable, approximating 5% of the adult population (Davis & Rafaie, 2000). In turn, Easter (1997) suggests that one person in five experiences some degree of tinnitus whereas Axelsson & Ringdahl (1989) conducted a large community study in Gothenburg, Sweden, where 14.2% of the population were found to suffer from tinnitus "often" or "always", and 2.4% claimed that their tinnitus "plagues me all day". However, patients for whom tinnitus is a problem report a wide range of tinnitus severity, not necessarily the loudest or most constant noises. These individuals have a variety of complaints associated with tinnitus: including insomnia; concentration problems; irritability; and depression.

Despite a relatively high prevalence, this auditory system disorder is still not clearly explained and debate still rages about the underlying mechanisms that invoke it. Nevertheless, studies do exist concerning the inherent characteristics of tinnitus, and general tinnitus characteristics have been agreed upon by many authors (e.g. Meikle & Griest, 1987, 1991; Tyler, 1992; Meric, Gartner, Collet & Chery-Croze, 1998).

**Physical Characteristics of Tinnitus**

It is important to appreciate that firstly, not all tinnitus patients perceive their tinnitus in the same way, and secondly, that environmental factors and individuality play a significant part in the attitudes that tinnitus sufferers hold regarding their condition. Tinnitus matching studies (Stouffer & Tyler, 1989) indicate that sufferers with the same type, frequency and degree of tinnitus are not all equally bothered by it. Tinnitus is complex and subjective, interpreted differently by different people. In addition, there are other tinnitus traits that can be considered alongside loudness, traits that could arguably influence patient perception of their own tinnitus:

***Constancy vs. fluctuation.*** 55% of patients interviewed by Meikle and Taylor-Walsh (1984) reported that their tinnitus was usually constant, but the rest reported varying degrees of fluctuation. It would seem reasonable that tinnitus which is constantly present and unvarying might be more distressing than tinnitus which grows louder and recedes from day to day. Indeed, patients frequently comment that it is the unremitting nature of their tinnitus that bothers them the most (Meikle, Vernon & Johnson, 1984). Yet Meikle et al. asked a total of 1209 patients about both the severity of their tinnitus and about its tendency to fluctuate - or not - as the case may be. There was no correlation between the two ($r = 0.04$).

***Duration.*** The same authors also considered whether tinnitus persisting for a long time might seem more severe simply because of its duration. 1260 patients provided data that showed a slight tendency for patients with tinnitus of at least five years duration to give higher severity ratings than those who had had tinnitus for periods of two years or less (no correlation value given).

***Pitch.*** 68% of the tinnitus sufferers interviewed by Meikle and Taylor-Walsh (1984) were best matched with frequencies above 3000Hz. As such, Meikle et al. also suggested that pitch could be a parameter of tinnitus severity, concluding that high-pitched tinnitus would be more aversive than low-pitched tinnitus. 710 patients also provided data on tinnitus frequency but no correlation existed between pitch and severity ($r = 0.002$).

***Type of sound heard.*** Miekle et al. (1984) also gave their participants the opportunity to indicate which sounds - in a list presented to them - most closely resembled their tinnitus. The types of sounds chosen included such items as "ringing" and "hissing".

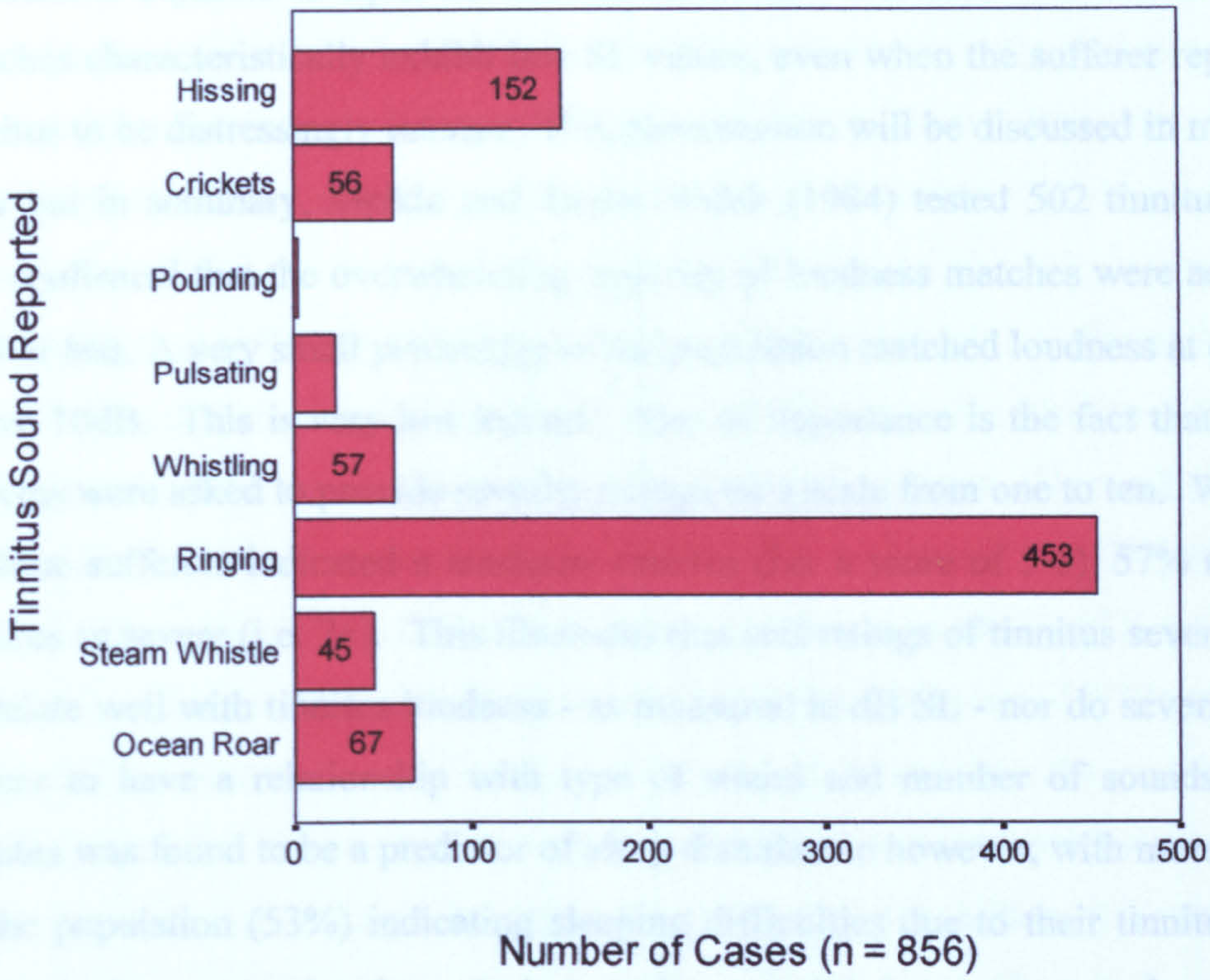



Figure 1: Distribution of sound types most closely resembling the tinnitus sensations of clinical patients. (Taken from Meikle et al., 1984).

It was speculated that different sounds were not equally aversive. For example, "ocean roar" may be more tolerable than "steam whistle". With the sample limited to those patients complaining of only one sound (613 patients), analysis indicated that "ringing" was associated with much greater severity ratings than "hissing" ($p<0.05$) but other comparisons were unclear - possibly due to the smaller numbers involved.

**Number of sounds heard.** Near half the sample reported complex tinnitus sounds (i.e. more than one sound). Comparison on number of sounds showed those reporting four or five sounds were significantly more likely to have higher severity ratings than those who checked one or two sounds. In addition, Meikle and Taylor-Walsh (1984) reported 57% of sufferers admit the presence of only one sound.

Meikle and Taylor-Walsh (1984) also attempted to match tinnitus noises with external tones in order to measure loudness. The method used determined the sensation level (SL) of an external sound with frequency matched to the pitch of the tinnitus and loudness is adjusted to equal the tinnitus sensation. It is now well known that such matches characteristically exhibit low SL values, even when the sufferer reports their tinnitus to be distressingly intense. This phenomenon will be discussed in more detail later but in summary, Meikle and Taylor-Walsh (1984) tested 502 tinnitus patients and confirmed that the overwhelming majority of loudness matches were achieved at 6dB or less. A very small percentage of the population matched loudness at or slightly above 10dB. This is very low indeed. Also of importance is the fact that the same patients were asked to provide severity ratings on a scale from one to ten. While 34% of these sufferers indicated a moderate tinnitus (i.e. a score of 5-6), 57% rated their tinnitus as severe (i.e. 7+). This illustrates that self-ratings of tinnitus severity do not correlate well with tinnitus loudness - as measured in dB SL - nor do severity ratings appear to have a relationship with type of sound and number of sounds. Severe tinnitus was found to be a predictor of sleep disturbance however, with more than half of the population (53%) indicating sleeping difficulties due to their tinnitus. There were no clear, age-related trends in severity, nor did there appear to be significant differences in severity between the sexes (Meikle, Vernon & Johnston, 1984). However, many patients reported that their tinnitus caused problems in concentrating and in maintaining normal social relationships with their families, friends and work associates, also interfering with attempts by the individual to relax. In addition, Meikle et al. asked if tinnitus caused problems sleeping. A direct relationship was found between tinnitus severity and the people reporting sleep disturbance (r-value not given; $p<0.01$). However, the authors do not make any suggestion as to whether this sleep disturbance is due to the tinnitus or due to worrying about tinnitus, a seemingly important distinction. Overall, Meikle et al. provided data demonstrating that tinnitus severity does not seem to be related to any other attributes of tinnitus, except for the number of sounds reported.

Rizzardo, Savastano, Maron, Mangialaio and Salvadori (1998) reported that in most cases (60%), tinnitus is associated with light hearing loss (<35dB); a more severe hearing loss in 28% of cases; and for 12% of people, hearing is perfectly normal. Evidence suggesting differences due to gender are inconclusive. In their clinical sample, Coles, David, and Haggard (1981) reported a small but significant trend of higher tinnitus prevalence in females below the age of forty. However, both Miekle and Greist (1987) and Meric et al. found the exact opposite. Erlandsson, Rubinstein, Axelsson, and Carlson (1991) used self-report scales and claimed that men report louder tinnitus than women. Difficulties in falling asleep were reported more often by male patients and left-sided tinnitus and noise-induced hearing loss were also more predominant in males, although women reported higher anxiety.

Meikle and Taylor-Walsh (1984) updated a survey of 531 tinnitus sufferers by Vernon (1978) based on interviews of 1806 tinnitus patients visiting the Tinnitus Clinic at the Oregon Health Sciences Center over the course of several years. They asked sufferers about a host of tinnitus characteristics before they underwent detailed audiometric testing. The sample population included many more males - 69% of the total population - than females, and the most represented age group was 50-70 years of age, with relatively few tinnitus sufferers under twenty. Interestingly, the gender bias was at its strongest for the younger age groups, though this was counterbalanced in later years, no doubt due to the greater longevity of women. In addition, it is probable that younger men ended up with tinnitus through the increased likelihood of encountering industrial noise during their working lives. It was also evident that the clinic's population was heavily weighted towards those with tinnitus of at least five years duration. This would be as many of these patients were referred to the clinic by their doctors after other remedies and treatments had failed to have an effect (Meikle & Taylor-Walsh, 1984). Many of these participants reported that their tinnitus was originally quite mild, but had grown louder over a period of years. It is reasonable to assume that such patients only sought medical help after their tinnitus had become more distressing. Asking about personal habits and general health history, Meikle and Taylor-Walsh discovered that 26% of men and 21% of women smoked. A higher percentage of men than women (74% and 69% respectively) drank coffee regularly - important when considering the tendency of caffeine to exacerbate tinnitus - leading to clinical recommendations to refrain from drinking caffeinated products where possible. 36% of men and 28% of women also reported some sort of head injury in the past, though no correlation existed between incidence and tinnitus frequency. Of more relevance was the finding that 23% of males and 36% of females reported past ear diseases. Here, a significant correlation did exist with tinnitus frequency. A disproportionate number of those patients reporting some sort of ear disease had their tinnitus best matched to frequencies at or below 1000Hz, indicating conductive hearing loss. Overall, 40% of tinnitus sufferers reported high blood pressure and 50% reported allergy problems. Far more important was that 66% of the population visiting the tinnitus clinic reported exposure to loud noises in the past. This finding was expected, as was the fact that 80% of men had been exposed to such sounds compared to only 31% of women. As ever, the explanation for this large discrepancy is that such noise exposure is most likely work-related. Jastreboff, Gray, and Gold (1996) reported that roughly 40% of their tinnitus patients exhibited hyperacusis. They reported that this subpopulation is particularly difficult to treat, as exposure to even mild sounds can provoke enhancement of the tinnitus sensation for extended periods. Certainly, the physiology of hearing is a complex phenomenon, with tinnitus feedback from this process "...embracing an infinite variety of auditory sensations that are not caused by externally applied stimulation" (Kemp, 1981; page 1388). Tinnitus is not a disease, but instead a symptom of sensory feedback in the CNS, very much like the static or buzzing occurring as feedback in an electrical system. One group of researchers even went as far as describing tinnitus as being a type of sensory epilepsy (Brown et al., 1981), a notion supported by the fact that certain anti-seizure drugs have had an effect in attenuating tinnitus (Billue, 1998). The same author notes that over 200 other medications can actively produce tinnitus as a side-effect.

**Psychological Effects of Chronic Tinnitus**

In addition to hearing loss and depression, there are many other features related to the condition. A lot of tinnitus sufferers report considerable distress, and this is reflected in high levels of insomnia (Miekle, Vernon & Johnson, 1984); fear/anxiety (Wilson, Henry, Bowen & Haralambos 1991; Attias et al., 1995); concentration difficulties; irritability; and an inability to relax (Jakes, Hallam, Chambers & Hinchcliffe, 1985; Erlandsson, Hallberg & Axelsson, 1992; Tyler et al., 1992). So much distress in fact, that some consider or are driven to suicide (Tyler & Baker, 1983). It is common for patients to report that their tinnitus as worse when under stress, though it is not clear whether this perception is technically accurate. However, several explanations exist to explain the relationship between stress, psychological distress and tinnitus (Wilson, Henry & Nicholas, 1993). Firstly, an increase in tinnitus loudness could result in greater reactivity to other stressors, making it appear that these stressors have led to a worsening of the tinnitus sensation. Secondly, the presence of environmental stress may lead to a more negative perception of tinnitus without any actual change in the tinnitus itself. Finally, that environmental stress may lead to a worsening of tinnitus intensity through some physical process. It is also possible that those people who complain the most about tinnitus are either more reactive than usual to aversive stimuli, or that they experience other psychological difficulties yet incorrectly attribute their distress to the tinnitus rather than these other factors. It would therefore be of interest to compare tinnitus with similar theoretical relationships such as that between stress and chronic pain. Much has been made of the relationship between chronic pain and depression, with a strong link having been established some years previously (Von Knorring, 1965). Patients with major depression have a high rate of pain-related complaints and patients with chronic pain have a high prevalence rate of major depression. Since the above suggests tinnitus maintaining a similar relationship with depression, and that commonalities exist between tinnitus and chronic pain, this relationship will be discussed in detail later.

Most tinnitus patients make a successful adaptation to the presence of phantom sounds but for those who fail to adapt, tinnitus may become a source of significant distress. As shown above, studies attempting to link psychoacoustical characteristics of tinnitus - such as loudness and pitch - with subjective severity have consistently failed to produce dependable results. For example, Meikle, Vernon, and Johnston (1984) reported a poor correlation between perceived severity and emotional impact, whereas Stouffler and Tyler (1990) found a significant correlation between annoyance and loudness. Yet, while tinnitus can become a serious threat to individual wellbeing over time, it is usual for tinnitus sufferers to not seek help until it becomes a major aggravating factor in their lives. This suggests not only that the perceptual component of tinnitus is important, but that the psychological responses and coping mechanisms utilised can lead to either enhancement or habituation. In support of this, House (1981) found no difference in the quality and intensity of tinnitus between two groups of patients: those disturbed by their tinnitus and those who were not. Therefore, there will be psychological factors affecting subjective response to the condition. This is a vitally important consideration. As will be seen, the main measure of tinnitus severity used in this Thesis will be subjective, not objective. For this reason, it is important to state that perception of tinnitus severity is a complex and subjective phenomenon that is distinct from the underlying noise level of the tinnitus sensation.

Many authors (e.g. House, 1981, 1991; Attias et al., 1995; Meric et al., 1998) note that a large proportion of their participants were able to relate the onset of their tinnitus to some event or disease which took place at roughly the same time. Among the possible causes, psychological distress was the most frequently cited. It is also known that while tinnitus is objectively weak (Meikle & Taylor-Walsh, 1984) it can have an undeniably adverse effect on the life of the sufferer (Jakes, 1997); there is a well-established association between tinnitus and psychological morbidity (O'Conner, Hawthorne, Britten, & Webber, 1987). Considering that chronic tinnitus is a long-term condition distressing to the sufferer, it is of no surprise that many patients become depressed.

**Tinnitus and Depression**

The nature of any depressive illness is such that individuals are not only despondent in mindset, but that they also perceive and react to events in a negative way. They are often less resilient and less able to cope with their problems and are consequently less tolerant of any associated discomfort, such as tinnitus. Dobie and Sullivan (1998) estimated that the prevalence of current major depression in the general adult population is 5%. This increases to 10% in adults receiving medical care. They also state that the likelihood of lifetime prevalence (one or more bouts) is approximately 10-15% in men and 20% in women. Berrios, Ryley, and Garvey (1988) assessed the psychiatric morbidity of 207 patients receiving treatments for inner ear disorders. As a group, these patients were found to score more highly on the General Health Questionnaire (GHQ) - i.e. more problems - than both non-patients and patients affected by other forms of physical disease. Within the inner ear disorder group, patients with tinnitus were found to have the highest scores for depression and anxiety. This finding is supported by many other researchers (e.g. Stephens & Hallam, 1985; Harrop-Griffiths et al., 1987; Attias et al., 1995). Sullivan et al. (1988) used the Hopkins Symptom Checklist (SCL-90) to assess 40 tinnitus patients. According to the criteria of this psychiatric inventory, 68% of these patients had current depression, with 78% having experienced a major depressive episode at some point in their lifetime. Budd and Pugh (1995) accessed 109 tinnitus sufferers and found a significant correlation between tinnitus severity and depression, as scored by the Beck Depression Inventory (BDI). However, while they used nine items to measure loudness, unpleasantness and annoyance caused by tinnitus, the authors did not publish their exact questions, nor did they provide statistical analysis to show which items correlated with depression and which did not. Sullivan et al. (1988) also investigated the known prevalence of depression in tinnitus sufferers, noting that out of a self-selecting subset of forty-one patients with disabling tinnitus, 78% had a significantly greater prevalence of depressive states in the past when compared to controls. Folmer et al. (1999) reviewed 436 patients at a tinnitus clinic to provide additional information on the relationship between tinnitus severity, loudness and depression. 151 patients (34.6%) indicated a history of depression, with another 121 (28.7%) reporting current depression but no louder tinnitus sensation than those without. This is a much lower prevalence than that reported by Sullivan et al. but certain methodological differences existed. For example, Folmer et al. diagnosed depression with the SCL-90 whereas Sullivan et al. used health history questionnaires. Still, both concur that loudness does not equate with severity, a reasoning soundly supported by both Meikle et al. (1984), and Kuk, Tyler, Russell, and Jordan (1990). The latter reported that tinnitus loudness ratings accounted for only 32% of the variance in their assessments of the perceived handicap of tinnitus. Though the point will be made again elsewhere, tinnitus perceived at low intensity does not automatically translate into a less severe problem, just as tinnitus perceived at a greater intensity does not necessarily lead to more severe levels of distress. Work such as Folmer et al. (1999) indicates that depression and tinnitus severity are linked. Certainly, this has been confirmed in a number of studies (e.g. Kearney, Wilson & Haralambous, 1991; Budd & Pugh, 1995), and the importance of psychological factors is generally acknowledged (Tyler, Aran & Dauman, 1992). It is noteworthy that Attias et al. (1995) found tinnitus loudness to be lower in help-seekers than other sufferers not seeking treatment. Help-seekers also displayed more psychiatric symptoms. This supports the stress-diathesis model whereby more vulnerable people are unable to tolerate milder tinnitus.

Several studies have examined the psychopathology of sufferers of chronic tinnitus. Stephens and Hallam (1985) were able to demonstrate that tinnitus sufferers score significantly higher on depression and anxiety self-rating scales than control groups. In addition, Lechtenburg and Schulman (1984) interviewed a separate group of tinnitus sufferers and found a 12% prevalence for psychiatric disorders; 75% of this subgroup demonstrating clinical depression. Furthermore, in trials using self-rated questionnaires: 56% of tinnitus patients complained of insomnia; 70% of emotional difficulties (anxiety and depression); and a total of 93% reported adverse effects on their lifestyle (Tyler & Baker, 1983). Such evidence suggests that aside from physical illnesses directly related to tinnitus, there is an association between chronic tinnitus and psychiatric illness. However, it must be stressed that this earlier literature was plagued with methodological flaws. The most common of these was the use of study populations pre-selected for psychological treatment (sampling bias). Many studies also failed to compare results with a control group, and lacked structured psychiatric interviews to accurately define psychiatric illness. One of the first studies to meet such demands was Harrop-Griffith et al. (1987). Twenty-one tinnitus patients and fourteen control subjects were given an abridged version of the National Institute of Mental Health Diagnostic Interview Schedule (NIMHDIS), which generates diagnoses for a wide range of both past and contemporary psychiatric disorders. In general, patients with chronic tinnitus were audiometrically characterized as having a mild sensorineural hearing loss limited to the higher frequencies. The measurable loudness of tinnitus - as would be expected - did not correlate well with the patient's own perception of their tinnitus. Thirteen (62%) of the tinnitus group were discovered to have had one or more major depressions in their lifetime compared to three (21%) in the control group. Also, ten (48%) of the tinnitus group were clinically depressed at time of interview compared to only one (7%) control. There was also a significant difference in the number of somatic symptoms reported between the two groups, with the tinnitus sample reporting more. However, Harrop-Griffiths et al. stated that in all likelihood, this increased prevalence was due to the presence of major depression. Patients with both major depression and tinnitus held over twice the number of somatic symptoms than patients with tinnitus alone. When responses on the SCL-90 were directly compared to the control group, tinnitus sufferers were only significantly different with regards to somatization. However, tinnitus sufferers with current major depression had significantly higher scores on all scales. When this latter group was compared with tinnitus sufferers without a current depression, they still rated higher on all scales, with the exception of phobia and paranoia. This suggests that non-depressed tinnitus patients are more similar psychiatrically to the control group than their depressed fellows. The tinnitus group also reported a significantly more problems when tested on the Chronic Illness Problem Inventory. Specifically, they reported significantly more severe problems with: sleep, cognition, sexual performance, contact with family and friends, medical interaction, marital difficulty, and illness focusing.

Harrop-Griffiths et al. (1987) also reported high rates of psychopathology in tinnitus sufferers, with an 80% lifetime likelihood of major psychiatric illness in patients with chronic tinnitus, compared to 43% amongst their control group. Major depression was by far the most frequent lifetime and current diagnosis, with two possible explanations for such a high rate. Firstly, tinnitus is an extremely aversive symptom causing difficulty in diverse areas of the patients' life, with depression developing as a secondary reaction. This is supported by Hallam, Rachman and Hinchcliffe (1984) who emphasised that while 18% of their sample had tinnitus, only 2% reported being significantly affected by it. Hallam et al. suggested that it is normal to habituate to tinnitus, gradually becoming less disturbed by it. Any lack of habituation in a particular individual must be due to personality characteristics or the development of depression. Major depression has been demonstrated to be a frequent secondary reaction to many illnesses, causing amplification of somatic components as well as an increase in the perceived disability caused by medical illness (Bridges & Goldberg, 1985; Matthew & Weinman, 1981). Patients attending a speciality clinic for chronic tinnitus may simply be those more likely to fail to habituate to or cope well with tinnitus. Harrop-Griffiths et al. (1987) showed that individuals with both chronic depression and tinnitus have significantly more problems. A second possibility is that depression is the primary illness, that the increased complaints of tinnitus severity are secondary - a result of the tendency of depressed individuals to complain about and amplify vague and non-specific medical symptoms. People with major depression have been found to have significantly more non-specific somatic complaints than controls (Matthew & Weinman, 1981). Moreover, Waxmen, McCreary & Weinret (1985) found that when comparing 51 depressed patients with 51 controls, not only did depressives have significantly more symptoms and higher severity scores, but 49% of the depressed patients complained of tinnitus, compared to 11.8% of the controls. From the above, it is clear that differences between chronic tinnitus sufferers and people without tinnitus are robust. Nevertheless, we must not fall into the trap of generalizing these findings to all patients with tinnitus. In many studies, participants were a selected sample referred to tinnitus clinics. The presence of psychiatric illness may be the main factor bringing these people to medical attention in the first place, whereas community studies identified large numbers of chronic tinnitus sufferers who do not visit their doctor to discuss their tinnitus (Government Statistical Service, 1983).

**Tinnitus and Suicide**

Subjective tinnitus severity spans a broad spectrum of distress, from clinical non-significance through to a disabling condition from which an individual may - in desperation - seek to escape by attempting suicide (Frankenburg & Hegarty, 1994). Lewis, Stephens & McKenna (1994) reported four deaths from suicide occurring among tinnitus sufferers attending the Welsh Hearing Institute in South Glamorgan between March 1990 and April 1991. Since this incidence seemed remarkably high, the authors felt further investigation was required. It is known that suicide is associated with mental illness in 90% of cases, with depressive illness in particular accounting for 60%. In addition, men are more likely to end their lives than women; with marriage, employment and social integration appearing to be protective factors (Lewis et al, 1994). The authors received case reports from a number of practitioners, gathering information on 28 tinnitus sufferers who had committed suicide. Certain types of tinnitus (e.g. pulsating or whistling noises) and other audiological parameters, such as degree of hearing loss or presence of hyperacusis, were not found to be in excess in the sample. The majority were male, with ten individuals having a history of mental illness prior to tinnitus onset (two suffering schizophrenia, five with major depression, two with an anxiety state and one with hysterical fits). In addition, four others had problems with alcohol. At time of death, eighteen of the tinnitus sufferers were thought to be depressed - ten diagnosed as such by a psychiatrist and the remainder reported as being depressed by their family or their general practitioner. No information was available regarding how many were receiving treatment for depressive illness at the time of suicide, but seven of the sample were reported as being anxious, distressed or desperate with only one reported as not being known to suffer from any sort of mental health symptom. Five of the group were known to have made at least one previous suicide attempt in the year prior to death, and three others were reported to have an associated physical illness - two with ischaemic heart disease and one with an osteoblastoma. Audiological parameters were also ascertained with tinnitus having been present in the study population for an average of 24 months. Nine of these had killed themselves within a year of tinnitus onset (see Figure 2, page 17).

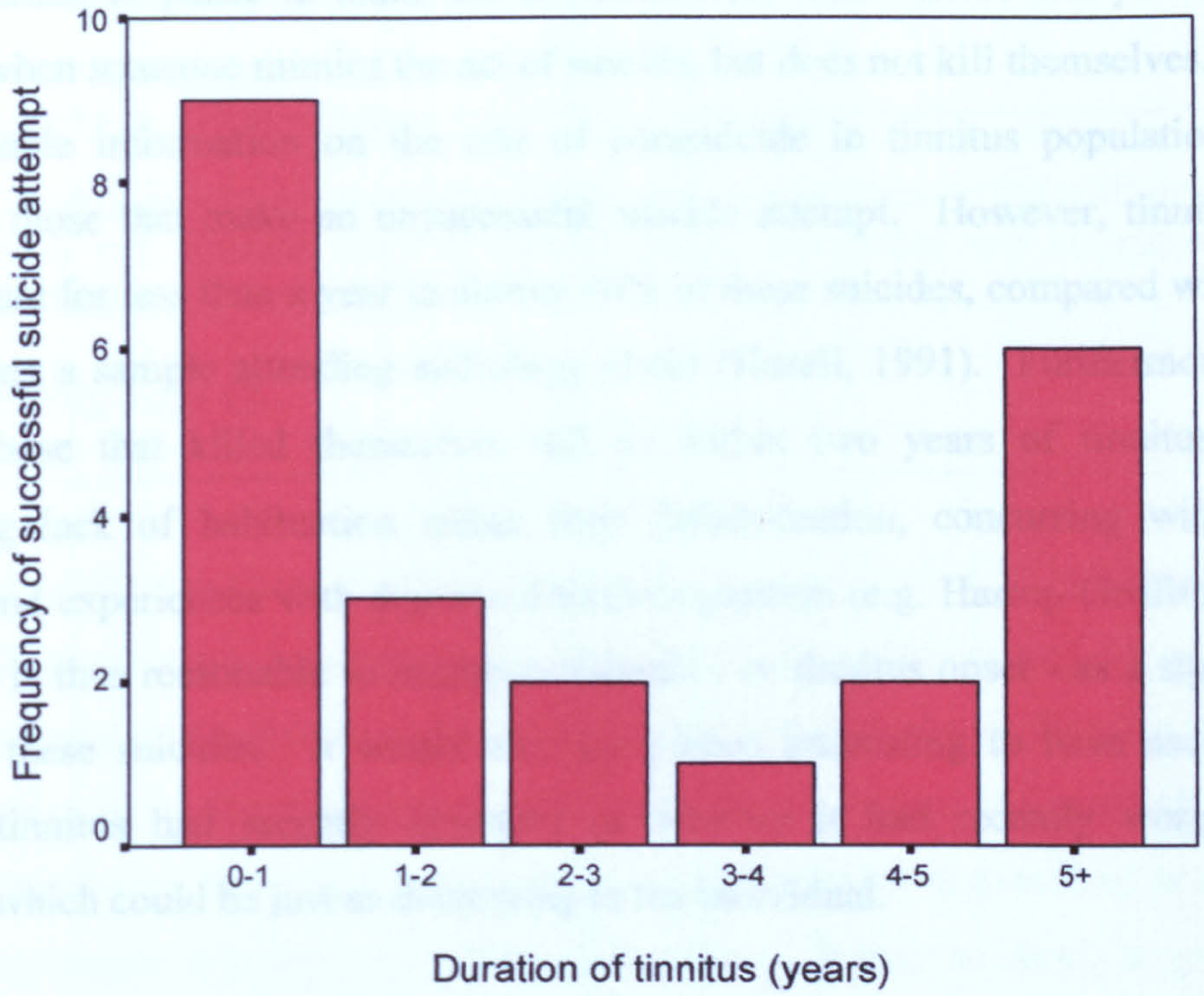



Figure 2: Duration of tinnitus from onset to death. (Adapted from Lewis, Stephens, & McKenna, 1994).

Method of suicide employed did not appear significant, though suicide was more than twice as common in male tinnitus sufferers than women. It is important to note that this does not reflect a bias in tinnitus populations as both men and women are equally represented (Axelsson & Ringdahl, 1989). Average age of death was 57.1 years but the distribution was skewed towards old age, with over 70% of the suicide victims being over the age of fifty. It is thus reasonable to assume that suicide among tinnitus sufferers is more common in the elderly and this concurs with the tendency for suicide in general to become more common with age. In summary, psychiatric symptoms were present in more than 95% of subjects at time of death, depressive symptoms in 70% (over half having seen a psychiatrist) and alcohol abuse in 17%. 40% were unmarried and 30% lived alone, reflecting a sense of social isolation. All of this is to be expected of suicide cases but the level of psychiatric morbidity is well in excess of what would normally be expected of tinnitus sufferers, despite their well-recognized propensity towards psychiatric illness.

It is important to pause to make the distinction between suicide and *parasuicide*, which is when someone mimics the act of suicide, but does not kill themselves. There is no reliable information on the rate of parasuicide in tinnitus populations, nor regarding those that make an unsuccessful suicide attempt. However, tinnitus had been present for less than a year in almost 40% of these suicides, compared with only 15% among a sample attending audiology clinic (Hazell, 1991). Furthermore, over half of those that killed themselves did so within two years of tinnitus onset, suggesting lack of habituation rather than dishabituation, concurring with other theories and experiences with depressed tinnitus patients (e.g. Harrop-Griffiths et al., 1987). It is thus reasonable to implicate tinnitus - or tinnitus onset - as a significant factor in these suicides. It would also have been interesting to have ascertained whether tinnitus had recently appeared or whether it had recently worsened, a situation which could be just as distressing to the individual.

It is difficult to state exactly what contribution tinnitus may make in the decision to commit suicide. The high incidence of suicide at the clinic of Lewis et al. (1994) was estimated at 118/100,000 per year, compared to 9/100,000 in South Glamorgan - including Cardiff - as a whole (Watura & Vetter, 1991), suggesting tinnitus sufferers to be a high risk group. The fact that half of those who eventually killed themselves did so within two years of onset implicates tinnitus as being a significant and negative life event - especially as other tinnitus parameters did not appear to be associated with suicide. Tinnitus suicides were also associated with other well-established risk factors; mental illness, social isolation, old age, male gender etc. It is unlikely that tinnitus acts on its own in significantly increasing the risk of a suicide attempt. However, it should be considered to be a predisposing factor in complex interaction with other variables. The vast majority of tinnitus sufferers do not end their own lives, yet are prone to a higher than expected level of mental illness and have to endure a chronic, disabling condition requiring the support and understanding of those around them. As such, tinnitus may be considered an excellent example of a life stressor, alongside such factors as unemployment and bereavement.

**Tinnitus Annoyance and Psychopathology**

> "Tinnitus victims have a physiological dysfunction somewhere in the auditory system that produces real distress, distress that is neither imaginary nor indicative of an unreasonable tendency to complain."
>
> **Vernon (1976). Page 18.**

However it really functions, tinnitus remains a clinical and scientific enigma. As will be seen, there are many hypotheses of tinnitus generation (Eggermont, 2000), yet no robust treatment exists to help deal with the condition. The simple fact that there are no outward signs of tinnitus has hampered research. Clinicians and researchers have to rely on the description of the patient, with the sensation being described in a variety of ways or compared to tones superimposed on noise. It may be steady or pulsating, and can change in character from day to day and throughout the day.

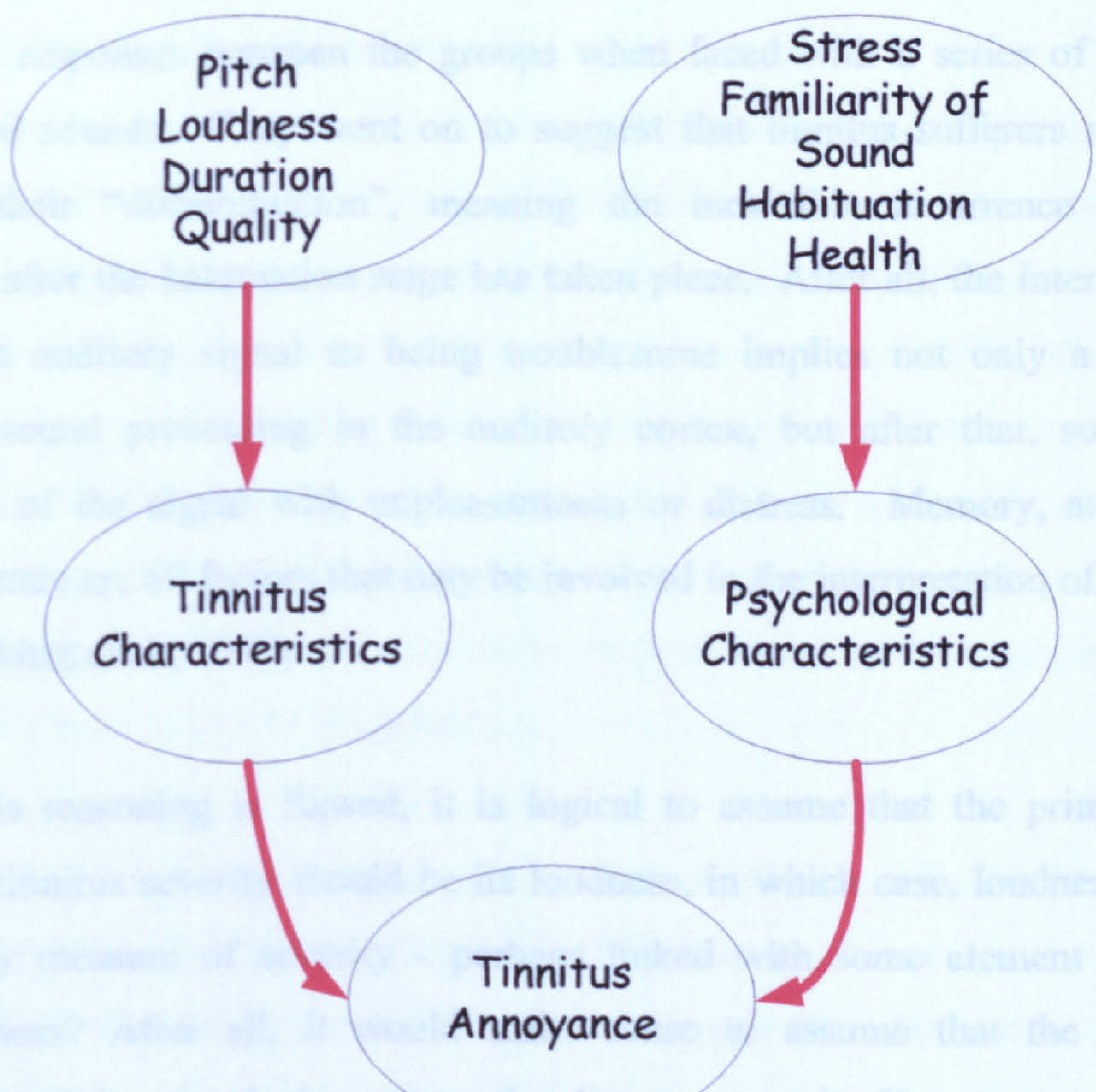



Figure 3: Factors contributing to tinnitus annoyance (Tyler, Aran & Dauman, 1992).

As can be seen in Figure 3 (page 19), there are two main factors contributing to tinnitus annoyance: the physical features of the tinnitus, and the psychological characteristics of the individual. It is thought to be easier to adapt to a continuous sound than an intermittent one, but this can depend on the duration of any quiet periods, and on the nature of the tinnitus sensation. In addition, it is logical to assume a higher pitch or a louder, more unpleasant quality of tinnitus is more annoying than a noise that is more passive, yet as will be seen, this is not the case - as mentioned previously, we must maintain the distinction between tinnitus characteristics (i.e. a louder noise) and psychological characteristics (i.e. increased distress). Less is known about the psychological factors that contribute to tinnitus annoyance. Simply put, some people are better able to cope with stressful situations than others. Hallam, Rachman and Hinchcliffe (1984) suggested that some patients are better able to habituate to the tinnitus sensation, becoming less disturbed as time passes. Investigating this, Carlsson and Erlandsson (1991) measured skin conductance and heart rate in two different groups of tinnitus patients; defined as 'complainers' and 'non-complainers'. The authors were unable to find any significant difference in habituation responses between the groups when faced with a series of unpleasant, high-pitched sounds. They went on to suggest that tinnitus sufferers may instead differ in their "dishabituation", meaning the inevitable recurrence of tinnitus annoyance after the habituation stage has taken place. After all, the interpretation of an aberrant auditory signal as being troublesome implies not only a process of conscious sound processing in the auditory cortex, but after that, some sort of association of the signal with unpleasantness or distress. Memory, attention and emotional state are all factors that may be involved in the interpretation of the tinnitus sensation (Mirz et al., 1999).

Though this reasoning is flawed, it is logical to assume that the principal factor governing tinnitus severity should be its loudness, in which case, loudness would be the primary measure of severity - perhaps linked with some element of acoustic unpleasantness? After all, it would make sense to assume that the greater the abnormality of the signal, the greater the distress caused. However, more modern theories (e.g. Jastreboff, 1990) lay heavy emphasis on higher auditory processing and, more importantly still, the way in which the individual reacts to the tinnitus signal. These hypotheses highlight independence between tinnitus loudness and tinnitus distress that is well-supported in the literature (e.g. Baskill & Coles, 1999). This independence is not absolute, as an increase in loudness will often provoke greater distress over the short term, and vice-versa. Yet in the long-term, research comes down in favour of a more paradoxical association. Epidemiological investigation has shown that over the years, the most common change in tinnitus loudness is for it to increase whereas annoyance levels reduce over time (Coles, Smith, & Davies, 1990).

It is worth repeating that when attempting to determine tinnitus levels, it is often difficult to decide whether patient tolerance is slight or if the tinnitus itself is extreme. Keep in mind that the constant presence of the tinnitus sound is extraordinarily irritating. People with normal hearing may comment that sounds of 20dB or even 40dB or more are commonplace and not bothersome, but these sounds are not continuous. They can be avoided, altered or even escaped from. The ever-present noise of tinnitus may constitute a special type of annoyance that can only be appreciated by another sufferer (McFadden, 1982). Another quality of tinnitus that defies evaluation is its intimate nature. It comes from inside the head. It has an internal source with a special inertia that cannot be ignored. These psychological factors cannot be precisely measured, but nevertheless, they are important aspects of severe tinnitus (Vernon, 1976). Judging from some studies, it seems the severity of the symptom reported by the patient correlates less not the specific features of tinnitus (intensity, frequency, duration, timbre), but with related sleeping disorders, and difficulties with concentration and social relations (Rizzardo et al., 1998). Significantly, many patients report the noise becomes more noticeable when they feel tired, in the late afternoon, when they are ill, or when they are experiencing emotional conflict - suggesting either an increase in tinnitus awareness through demand, or a reduction in ability to ignore the sensation.

Tinnitus really can be debilitating, and several studies have looked at the way in which patients face their illness. Coping can be difficult. When it is, tinnitus is often given symbolic meaning and can become a scapegoat for other conflicts. In many ways, tinnitus is a purely subjective condition, so lends itself well to study of how signs and symptoms are interpreted by the individual. Rizzardo et al. (1998) reported mean values for depression to be below threshold for Zung's Self-Rating Depression Scale, indicating that tinnitus sufferers were not generally depressed. However, results on the State-Trait Anxiety Inventory showed a level of state anxiety significantly higher than normal, though this was not for trait anxiety. In personality tests, extraversion was significantly lower than expected, while neuroticism tended to be higher. More than 50% of participants suffered from psychological symptoms or somatic symptoms before tinnitus onset and, interestingly, this number rapidly increases afterwards. The prior existence of psychological symptoms in such a large minority of participants suggests that many individuals may have a psychological disposition to suffer more from tinnitus, or to be more susceptible to its onset. This compliments work by Erlandsson et al. (1991) who found that patients in a 'low' mood experienced significantly more intense and severe tinnitus, stress, irritation, concentration difficulties and anxiety.

Why do some people cope with tinnitus while others do not? One possibility was suggested by Hallam, Rachman and Hinchcliffe (1984), namely that coping involves a habituation process by which the noise gradually fails to elicit emotional arousal. Thus, poor copers are those who, for reasons connected with either the nature of their tinnitus or their individual differences, fail to habituate. For example, it has been suggested that some tinnitus sufferers experience more rapid alterations in the signal/noise ratio, something which may interfere with the habituation process. However, Carlsson and Erlandsson (1991) failed to find support for their suggestion that individual differences alone account for the variations in ability to cope. Other theoretical explanations include learned helplessness (Jakes, Hallam, Rachman, & Hinchcliffe, 1986). From this perspective, tinnitus is viewed as an uncontrollable noise which can produce effects on mood similar to those observed in other contexts. Thus, it is possible to conclude that distressed tinnitus patients are reacting to their tinnitus as they might react to other aversive stimuli or negative life events. Since some individuals cope better than others, it is possible to separate chronic tinnitus sufferers into two groups: good copers and poor copers. Kirsch, Blanchard and Parnes (1989) compared such individuals with patients suffering daily headaches and some non-patient controls. They revealed that poor copers were similar to the chronic headache patients, and that good copers were similar to the control group. Poor copers were also significantly more depressed and anxious than good copers. Good and poor copers did not differ on the frequency of stressful life events, suggesting that more negative reactions to tinnitus are not simply the effect of other sources of stress.

Tinnitus is a problem that interferes with daily routine. Disturbance due to tinnitus can range from mild irritation to suicidal desires - a broad range dependent on numerous factors: individual ability to cope; personality; social factors; sleep disturbances; depression; and anxiety. House (1981) observed 150 tinnitus sufferers referred to a psychologist by their otologist. Roughly half reported their tinnitus severe and unrelenting. Many had exhausted all available treatment options and requested that physicians should do whatever they could to stop the noise. A sizable minority were willing to accept 'surgical treatment and the loss of their hearing' (p. 194) if the noise would stop. Some reported being incapacitated, whereas others restricted their activities and social life. According to House, patients reporting the most severe tinnitus sensations fall into three distinct psychological categories. She termed these as: depressive reaction; hysterical conversion reaction (i.e. neuroticism); and conversion reactions with schizoid features - the latter being a seriously disturbed group considered to have borderline personalities. The depressive reaction patients fared best with the treatment programme provided by House. These patients focused on their tinnitus and considered it their one major problem. When their depression was alleviated, they reported their tinnitus was less severe. The neurotic group also gained from the treatment to a lesser extent. They were seen to deny and repress their feelings, with House suggesting that their failure to cope stemmed from a refusal to see their disorder as anything other than a purely physical condition, refusing to accept a psychological interpretation. The third group - those classed as 'borderline' - had great difficulty with the prescribed treatment. Almost all failed to complete biofeedback training and were not considered good candidates for psychotherapy. As a result of her treatment, 80% of the interviewees reported a reduction in noise and disturbance along with better sleeping patterns, a better attitude towards themselves and a general increase in well-being. As treatment progressed, changes in attitude were apparent with most patients reporting they were beginning to see tinnitus as a problem that could be lived with. However, many of the statements by House seem sweeping and general, with clear-cut compartmentalization that may not adequately reflect reality. Further a description of her treatment programme is lacking, and House makes no mention of follow-ups to ascertain long-term effectiveness.

Halford and Anderson (1991b) demonstrated a close association between tinnitus and depression/anxiety. However, it remains unclear whether this disturbed state is a cause of tinnitus or a consequence of it. Some chronic tinnitus sufferers tend towards depression, somatization and compulsive behaviour. Some also demonstrated severe concentration difficulties (House, Miller, & House, 1977). Conversely, other studies (Reich & Johnston, 1984; Gerber et al., 1989) contrast strongly, reporting no evidence of any psychotic or neurotic traits. Further, Collet et al. (1990) found greater depression levels in male subjects, and hypochondria in those with a long history of the condition. However, the clinical population mentioned in most of these studies are likely to be biased - to a sizable yet unknown extent - towards the more severe cases of tinnitus. Many patients with mild tinnitus presumably do not seek medical help, and would be less likely to be found and asked to take part in research.

As will be discussed later, several studies have pointed to analogies between tinnitus and pain. As far as pain - and headaches in particular - are concerned, many studies have examined the personality characteristics of such patients, yet little has been done on the psychological profile of tinnitus sufferers. House (1981) was one of the first, distinguishing three groups of tinnitus sufferers through MMPI profiling. Increased anxiety and depression were found using the Crown-Crisp Experimental Index (Stephens & Hallam, 1985; Hallam & Stephens, 1985). Similarly, Tyler and Baker (1983) showed 36.1% of tinnitus patients reported despair, frustration, guilt, and depression. However, there are discrepancies. Gerber, Nehemkis, Charter, and Jones (1985) noted pathological-level scores for both anxiety and depression, with this being contradicted by Reich and Johnston (1984), who reported MMPI scores within normal limits. In a bid to clear the confusion, Collet et al. (1990) investigated the MMPI profile of 100 tinnitus sufferers. The mean psychopathology profile was again within normal limits. In addition, they found no evidence of previously suggested links between tinnitus and headaches (Collet, Cottraux, & Juenet, 1986). Interestingly, Hallam and Stephens (1985) did not find pathological depression in tinnitus sufferers, yet their sample ($n$ = 60) had the same number of males as females. Collet et al. had roughly twice as many males (63) as females (37) and did find a link. In addition, most of the above used the MMPI, even though there has been debate over its psychopathological validity (Collet et al., 1990). All that can be stated with certainty is that tinnitus patients have a mean MMPI profile that is not in itself pathological.

## Objective Measurement

A tinnitus measurement is referred to as 'objective' when it can be verified by an outside observer, but 'subjective' when only perceived by the patient. Yet the only clinically available objective measure of tinnitus is a psycho-acoustical description of pitch and loudness, which is in turn based on a subjective match between tinnitus and artificially produced external sounds (Goldstein & Shulman, 1981; Hallam et al., 1985). This is extremely difficult to achieve, partly due to temporal fluctuations in the tinnitus sensation, and partly due to unreliable measurement. It was commonly - and wrongly - assumed that degree of distress associated with the tinnitus sensation must correlate directly with the loudness of the signal. Following this logic, it was believed that an accurate method of determining tinnitus severity could be based upon comparison with the objective loudness (in decibels). Fowler (1945) was the first author to question this relationship between loudness and distress. Asking patients to compare their tinnitus with pure tones of his creation, he discovered the tinnitus sensation to be, at worst, 15dB. He thus advocated loudness matching as a way to convince patients that tinnitus was not loud enough to warrant consideration as a serious complaint. Similar work by Mizuochi (1954) reported that tinnitus volume is less than 10dB and as such, that it was not possible for it to interfere with hearing, or indeed with anything else. Reed (1960) supported this, stating that tinnitus loudness is rarely equivalent to pure tones of 20dB. He investigated 91 tinnitus patients, matching 87% of these with tinnitus at intensity beneath 20dB. Graham and Newby (1962) made a similar finding, noting that over half of their sample selected sounds under 5dB. Reed (1960) also provided a basic classification system for tinnitus according to seriousness:

***Mild tinnitus*** - not always present; noticed only in quiet places or at bedtime; patients can easily be distracted from thinking about tinnitus.

***Moderate tinnitus*** - constantly present; more intense in quiet surroundings; bothersome when patients attempt to concentrate and/or go to sleep.

***Severe tinnitus*** - very debilitating; patients complain bitterly; they cannot concentrate; they can think of little other than their tinnitus.

Certainly, many authors have measured the intensity of the tinnitus signal, and investigations have consistently yielded figures below 10dB in the majority of subjects. Indeed, Miekle and Taylor-Walsh (1984) stated that 51% of patients in their study estimated their tinnitus as being low enough to fall between 0-3dB. This means that complaints concerning tinnitus are about sounds judged by most to be so quiet that they could not possibly be of cause for concern. After all, these matched sounds are at a much lower order of intensity than those required to produce noticeable impairment on cognitive tasks; these being in the region of at least 80-90dB (Broadbent, 1981).

Following his experiences, Fowler (1945) suggested that tinnitus should be measured with a binaural loudness balancing technique. Here, pitch-matched tinnitus frequencies are obtained by adjusting the frequency of a pure tone in the opposite ear to the one being tested. The level of this tone is increased until its loudness equals that of the tinnitus. Fowler suggested that tinnitus loudness is the level of this tone above threshold - its sensation level (SL). Since most of his patients complained bitterly about the severity of their tinnitus, yet seeing that it was *not* loud, Fowler referred to this as the "illusion of loudness" (Fowler, 1942; cited Tyler & Stouffer, 1989; p.52). His instinct was to assume that his patients were exaggerating, and even noted that "city dwellers are almost constantly in the presence of noises louder than this" (Fowler, 1945; p.397), stating that treatment should consist of an educational process in which the sufferer must learn to rationalize symptoms and accept them at face value. Yet, an inherent weakness in objective measurement is that the matching process is attempted at frequencies corresponding to the tinnitus and, for the hard of hearing, this frequency range is likely to be where significant hearing loss exists.

Vernon (1976) attempted to link Reed's classifications with objective measurements, using external tones as the basis for comparison. When he did so, he also found that no coherent pattern emerged. He tried to explain away the discrepancy between tinnitus severity and distress with the phenomena of recruitment. Recruitment is most often encountered in ears that have suffered damage to the cochlea. It is characterized by the sensation of loudness growing more rapidly when faced with an increase in intensity than it does in undamaged ears. As such, sounds which are comfortable to a person with normal hearing may be more uncomfortable to someone experiencing recruitment. Therefore, loudness recruitment may complicate the issue, matching tinnitus sensations with external noises thought to be louder than they really are, rendering loudness measurements deceptively low. Goodwin and Johnson (1980) reasoned that if recruitment was present, the binaural loudness method would be inappropriate due to the comparison tone clashing with recruitment frequencies. Their belief was that patients with bilateral ear damage do not have a normal ear with which to hear reproduced tones effectively. As such, recruitment renders normal loudness balance tests utterly inappropriate. Their preferred methodology was to match the tinnitus sensation to a pure tone in the *same* ear - a task considerably more difficult for the participant - and this produced a clear threefold increase in tinnitus sensation levels. However, even this was not enough to claim a relationship between severity and distress, and they suggested that other methods needed to be devised in order to measure tinnitus severity objectively.

In addition, variation can stem from changes in the tinnitus signal itself - changes that may be induced by the test tone or by natural fluctuation. Stouffer and Tyler (1990) reported that 56% of tinnitus patients claimed a change in their tinnitus when it was present. Even worse, tinnitus can and does change drastically from one day to the next. Stouffer and Tyler also found that 50% of tinnitus patients reported daily loudness fluctuations which make it difficult to quantify the tinnitus sensation over time. In fact, they went as far as stating that as many as ten or twenty repetitions are needed to provide a reliable estimate. Measurements of this variability have been obtained by a number of authors (Goodwin & Johnson, 1980; Burns, 1984; Penner, 1988). Both Penner and Burns suggested that variability in tinnitus severity is considerably larger than that of the matched external tones. Penner measured tinnitus loudness (binaurally) in three patients and discovered that the loudness matches could vary over a 35db to 45dB range across a three-week period.

Over time, it has become clear that routine matching procedures have done more to obscure the facts about tinnitus than clarify them. The main cause of confusion is that the intensity of a sound matching tinnitus loudness holds no relationship with the distress experienced by the individual concerned. Either loudness has been consistently measured incorrectly or loudness is not related to distress. On the other hand, both statements may be true. Vernon (1976) concluded that different measures of loudness were necessary to clarify the situation as unlike Fowler (1945), Vernon believed the annoyance complaints. His important contribution was to insist that the methodology behind the measurement of tinnitus was not valid, that the distress experienced was not related to loudness or else some other factor, such as recruitment, was confounding the measurement.

In general, a 10dB increase in sound pressure level equates to a doubling of loudness but close to threshold, a more rapid rate of increase complicates the situation. Both this and the distorting effects of recruitment mean that looking at tinnitus loudness in quantitative fashion is difficult. An excellent example of this is the work of Tyler and Conrad-Armes (1983). With one particular participant serving as an example, loudness matching was undertaken at two separate frequencies, at tinnitus pitch and at normal threshold of hearing. Respectively, the loudness matches came out at 5.2dB and 62.0dB SL (sensation level), a massive difference, and one that shows the care with which loudness matching data should be interpreted. Tyler and Conrad-Armes also suggested a more mathematical approach, converting loudness levels from decibels into *sones*, claiming them to be a more suitable psycho-acoustical measure of loudness. Yet even with sones, they found no significant relationship between objective loudness and subjective distress. However, their tinnitus loudness estimates did correlate moderately with the masking level required to provide short-term relief. In addition, most professionals are unfamiliar with the sones unit (Tyler, Aran & Dauman, 1992), and the calculations required are complex. Still, the authors suggested that the use of sones is technically more appropriate for reporting tinnitus loudness, and that it is possible to convert into sones and then convert back to the equivalent sensation level for a 1000 Hz tone in a listener with normal hearing. For this method, it is necessary to measure threshold and sensation level for a tone judged to be equal in loudness to the tinnitus at its particular frequency. For example:

*"A patient with a 50dB hearing loss and a tinnitus loudness matched to a 5dB tone equates to a loudness of approximately 0.9 sones. This, in turn, is equivalent to a 39dB 1000 Hz pure tone in a listener with normal hearing".* (Tyler, Aran & Dauman, 1992; p39).

The authors admitted that their conversion was not completely accurate, but they were confident enough to suggest that it represented a 'reasonable approximation' (p. 39) in many cases. Even if this method of conversion is inaccurate, it still illustrates the effect that recruitment has in boosting the perceived volume of tinnitus in the sufferer. In another study, Hallam, Jakes, Chambers, and Hinchcliffe (1985) attempted to escape the decibel scale by converting decibels into both units of sensation level (SL) and into personal loudness units (PLU) - the latter being a mathematical function of the growth of loudness in the measured individual. By transforming the loudness match in this way, it was hoped to prove a relationship between loudness and distress. Such transformations correlated well with other audiometric parameters such as auditory threshold and most comfortable loudness level. However, even transformed logarithmically, traditional objective measures still failed to correlate with subjective and psychological measures of tinnitus complaint.

In his review of assessment procedures, McFadden (1982) pointed out a number of flaws in the measurement procedures used previously, not least being the difficulty in obtaining consistent responses from subjects, indicating the difficulty of the task demanded of them. Still, technical arguments aside, McFadden suggested that an internal sound may well behave rather differently to a weak external sound in its ability to formulate annoyance and distress. This is an argument first used by Vernon (1976), who stated that by the very nature of his clinic, he only ever saw tinnitus sufferers complaining of severe forms of the disorder. Even so, none of these individuals ever selected tones of more than 15-20dB to match against their tinnitus. In this, all these authors concur. So how can tinnitus be so disturbing to the sufferer? Under the decibel classification, a soft whisper is only 30dB and conversational speech is roughly 66dB. Without some other factor, a noise of 20dB - let alone 5dB - or even 50dB in the most extreme tinnitus case ever investigated by Reed (1960), should not be able to cause the distress it so clearly does. This continued speculation resulted in an investigation by Matsuhira, Yamashita, and Yasuda (1992). They produced a method of converting the tinnitus sensation level, coupled with the threshold of hearing frequency, into an absolute loudness unit known as the Effective Loudness Level (ELL). At the Fifth International Tinnitus Seminar, Coles, and Baskill (1996) reported on the ELL ratings of 103 tinnitus patients attending the Nottingham Tinnitus Clinic, with ELL values ranging from 0-65dB. Similar results were reported by Matsuhira and Yamashita (1996), with ELL ratings ranging from 6-63dB. Even though maximum loudness after correction was in the region of 60-70dB - a considerable increase on previous work - the common finding of the literature is that the median values are much lower. More specifically, 21dB in a specialist tinnitus clinic (Coles & Baskill, 1996), and only 16dB for otolaryngological patients (Matsuhira & Yamashita, 1996). Yet again, the same question must be raised. Why should tinnitus patients with respectively quiet tinnitus experience so much distress that they have to be referred to a specialist tinnitus clinic as a last resort?

In general, louder external sounds are more annoying, though this would not seem to be the case with tinnitus. Stouffer and Tyler (1990) found a correlation between subjective ratings of tinnitus loudness and annoyance reported by 528 tinnitus patients that was moderately high ($r = 0.56$). In addition, Penner (1983b) reported that continuous noise levels required to mask tinnitus must be increased as a function of duration. In other words, masking techniques become increasingly ineffective over time. Penner found no relationship between annoyance and the total change in masking volume required in a 30 minute interval, but did obtain a significant correlation ($r = 0.855$) between annoyance and the rate of change required for effective masking. The masker level had to be increased more rapidly to keep the tinnitus inaudible in individuals with the most severe tinnitus. In a separate study, Penner (1984) asked tinnitus subjects to rate annoyance caused by tinnitus occurring in their daily lives. The correlation between tinnitus loudness and annoyance was not significant ($r = 0.10$). This is a common finding, as individuals reporting mild tinnitus are by no means certain to select the weakest external noises as being the most appropriate to indicate what they hear themselves. Clearly, tinnitus loudness and annoyance vary greatly, so it is important to understand why some people are greatly disturbed by their tinnitus and others minimally so. It is logical to expect louder sounds to be more annoying than softer ones, but we should remember that many factors contribute to whether tinnitus will be annoying or not (Lindberg, Lyttkens, Melin, & Scott, 1984; Erlandsson, Hallberg, & Axelsson, 1992). Loudness is only one attribute contributing to the annoyance of a sound. Other factors also matter, including spectrum, temporal characteristics, and the individual psychological make-up of the individual. Although it is supposed that louder tinnitus will be more annoying and distressing, the relationship is multi-factorial and difficult to quantify.

The severity of tinnitus is difficult to assess for a number of reasons. For many, severity relates more to how much the tinnitus bothers them, regardless of noise. Clearly, an accurate assessment of tinnitus severity is vital for realistic attempts to alleviate the disorder. Miekle, Vernon, and Johnston (1984) were able to make a detailed analysis of over 1,800 patients seen at the Tinnitus Clinic of Oregon during a six-year period and were able to provide some useful generalizations. As we know, the majority of loudness matches (79%) are concentrated in an extremely narrow range; 4 to 6dB - helping to disprove the myth that loudness is related to distress. Unsurprisingly, no relationship could be demonstrated between loudness and severity, with correlations close to zero ($r = 0.07$). It was then suggested that most tinnitus sufferers experience similar sensations. As such, any differences that exist must be due to personal interpretation. At first glance, tinnitus loudness would seem to be the single most obvious way of quantifying tinnitus severity, the assumption being that this would provide an indication of what the sufferer is hearing, and that such a measurement could then be used in order to demonstrate to others what the sufferer is hearing. Therefore, it was believed essential that tinnitus loudness should be measured, and accurately measured (Tyler & Stouffer, 1989). Yet, as we have seen, there are huge - possibly insurmountable - problems with trying to achieve this. It may be that tinnitus loudness needs to be explicitly measured per individual, as Penner (1986) attempted. Unfortunately, this means that no comparison can ever be made with other people as individual perceptions of loudness differ drastically. i.e. Tinnitus loudness may be an arbitrary 50 units; but there would be no way to determine whether a loudness of 50 units for one person means the same thing for another. It has been assumed that the loudness of a tone can be predicted from its relationship to threshold (Tyler & Conrad-Armes, 1983) but if this is not the case, objectively comparing tinnitus loudness across subjects could be impossible.

It is clear therefore, that objectively measuring tinnitus through use of external sound is not particularly useful. However, other objective methodologies exist. Goodwin and Johnston (1980) suggested other ways to attempt measurement of tinnitus loudness. As well as subjective response, they considered reaction time. It is well documented that individual reaction time to stimuli is shorter for a more powerful stimulus (i.e. louder noise) than for a weaker stimulus (i.e. quieter noise). The authors measured reaction times to tones in tinnitus patients and found that they were shorter at the tinnitus frequency than at a non-tinnitus frequency. Because the tinnitus frequencies have had higher thresholds, the equal SL tones were probably louder, resulting in faster response. In addition, spontaneous electrical activity of the auditory nerve has been recorded from electrodes placed at the tympanic membrane, then analysed by what is known as a second-order autocorrelation function (Sininger, Eggermont & King, 1992). Schreiner and Snyder (1987) observed increased spontaneous activity in the auditory nerve of a cat following intravenous injection of salicylate. This activity fell back after administration of lidocaine, a drug shown to reduce tinnitus in some sufferers (Duckert & Rees, 1983). As is often the case with tinnitus, conflicting results were also found in experiments using magneto-encephalography. Some studies reported that auditory-evoked magnetic fields were different in tinnitus sufferers (Pantev, Hoke, Lutkenhoner, Lehnertz, & Krumpf, 1989; Shiomi et al., 1997) but others failed to replicate (Colding-Jørgensen, Lauritzen, Johnsen, Mikklesen, & Saermark, 1992). Researchers were therefore lacking useful, objective measurement and as such, the confirmation and validation of tinnitus for medical and legal purposes was thought to be impossible. Yet, with the development of brain imaging technology, new techniques have emerged that can reveal changes in activity in the central nervous system by measuring regional cerebral blood flow (rCBF). Several such studies have applied these techniques to tinnitus (Shulman, Strashun, Afriyie, Aronson, Abel, & Goldstein, 1995; Arnold, Bartenstein, Oestreicher, Roemer, & Schawaiger, 1996; Lockwood, Salvi, Coad, Towsley, Wack, & Murphy, 1998). These three studies imply the existence of an abnormal connection between the auditory cortex and the limbic system, as suggested by Jastreboff's neurophysiological model (Jastreboff, 1996). It is hypothesized that auditory systems mediating the tinnitus sensation may activate emotional control systems and memory systems in the hippocampus. The involvement of such cortical regions can go some way to explaining the distress and annoyance so commonly associated with tinnitus.

Objective measurement may give rise to some information about the general characteristics of individual tinnitus but does not allow for a prediction of severity, annoyance, distress or treatment outcome (Jastreboff, Hazell, & Graham, 1994). The main difficulty in evaluating tinnitus stems from the fact that it is effectively a subjective complaint. With tinnitus of similar levels described very differently by one sufferer compared to another, severity depends on individual personality dynamics and coping strategies. As such, the individual determines their own response and thus, the involvement of personality traits has been investigated by a number of authors (Hallam et al., 1984; Gerber et al., 1985; Collet et al., 1990). Such an interaction seems sensible to assume, especially since House (1981) showed a relationship between perpetuation of severe tinnitus and the presence of excessive stress. Several studies were conducted in search of specific psychopathological traits in tinnitus sufferers (Hallam, 1987; Briner, Risey, Guth, & Norris, 1990; Collet et al, 1990) that may manipulate expression of the symptoms. On the whole, these investigations have not proved any distinctive psychopathological profile though when considered separately, individuals have shown some evidence of psychopathological profiles (House, 1981; Gerber et al., 1985; Collet et al., 1990; Attias et al., 1995).

Since we are able to conceive of tinnitus as having some kind of magnitude, many authors reasonably concluded - though as we have seen, incorrectly - that both loudness and the amount of masking required should theoretically be related to the true severity of the condition. However, even the relationship between tinnitus and tinnitus masking is unclear. For example, Tyler and Conrad-Arms (1983) reported high correlations between loudness matches (in dB SL) and dB SL of noise required to mask the tinnitus sensation; ($r$ = 0.72, other ear) and ($r$ = 0.83, same ear). Yet, Burns (1984) found no relationship at all. Further, Baskill and Coles (1999) clearly state that there is no firm statistical relationship between tinnitus loudness and tinnitus severity, finding significant yet small correlations only ($r$ = 0.27-0.33). In particular, they make mention of patients with very mild tinnitus (objective measurement) reporting at least a moderate reduction in the quality of their lives whereas patients with objective tinnitus at least 10dB above the average reported only slight effects. Thus, isolated loudness matches tell us almost nothing about how troublesome tinnitus can be and do not appear to be of value. Certainly, whether assessing severity for clinical purposes or for compensation assessment, matching tests of tinnitus loudness are virtually worthless. In the case of research, loudness matches will still be unsatisfactory, unless the researcher is interested in measurement of objective changes in tinnitus loudness. Measurement of hearing thresholds tells us little about the degree of distress that an individual undergoes, though the UK National Study on Hearing (cited: Baskill & Coles, 1999) reported weak correlations between self-reported hearing difficulties and tinnitus annoyance. It is thought that those having greater difficulties in hearing external sounds will be more likely to focus on their own internal tinnitus sensation. In addition, since tinnitus is classed as a disability to begin with, the combination of tinnitus and hearing loss creates even greater difficulty for the listener, reflecting negatively on their quality of life.

There is a strong correlation between hearing loss and the presence of tinnitus in adults. Since the tinnitus signal is most likely to be the result of cochlear disorder, then the greater the disorder, the greater the likelihood of tinnitus occurring. Likewise, the greater the disorder, the more likely it is that abnormal neuronal signals will be generated and passed on the auditory cortex for processing. The failure of researchers to find a satisfying correlation between loudness and distress provides a lot of support for the more modern theories of tinnitus generation: (e.g. Jastreboff, 1996). His neurophysiological model leads us to expect a considerable degree of independence between objective measurement and the degree of disturbance that results. The latter depends heavily on higher cognitive evaluation of the tinnitus signal resulting from links between the limbic system and the autonomic nervous system. The lack of any true correlation between objective measurements and reported distress fit in very well with the concepts behind such a model.

## Subjective Measurement

> "Describing tinnitus loudness by sensation level measurements is not appropriate."
>
> **Tyler & Stouffer (1989). Page 57.**

As has been seen, a huge proportion of past tinnitus research has attempted to quantify tinnitus, trying to search out an effective way to quantify an objective tinnitus rating. Yet it is clear that describing tinnitus in such a manner is meaningless for practical purposes. Whatever the method used, psychoacoustic measurement does not provide a consistent relationship between tinnitus loudness and tinnitus distress. Therefore, research must turn to subjective measurement, with all the pitfalls and drawbacks thereof. In other words, tinnitus should be measured solely on the basis of how the individual is affected. Both clinically and legally, what really matters is the degree to which the tinnitus causes distress to the sufferer. During the nineties, several questionnaires were constructed in order to facilitate the evaluation of the effect that tinnitus has on the life of the sufferer. Learning the lessons of earlier researchers unable to measure tinnitus objectively, researchers instead sought to measure tinnitus subjectively. Several similar scales have since been constructed, each with their own relative merits. The first of these was the Tinnitus Effect Questionnaire (TEQ) developed by Hallam, Jakes and Hinchcliffe (1984). Here, a 40-item questionnaire was given to 79 patients reporting distressing tinnitus and from an evaluation of this study, a 51-item questionnaire was administered to a further 100 patients. Their factor analysis resulted in the identification of three factors contributing to tinnitus: sleep disturbance; emotional distress; and auditory perception difficulties. The questionnaire was also useful in that it separated tinnitus sufferers succinctly into two sub-populations, those that reported their tinnitus as being a 'significant annoyance' and those that did not.

The Tinnitus Handicap Questionnaire (THQ) was put forward by Kuk, Tyler, Russell and Jordan (1990). It was an attempt to evaluate the handicap of a particular tinnitus sufferer with respect to a norm, and allowing that handicap to be characterized in terms of the specific areas in which it appeared. Structure was determined by an initial list of 87 questions that were administered to 100 patients. As a result, 60 questions were eliminated due to the fact that they were either redundant or too insensitive to differences among patients. The original measure of internal consistency was a Cronbach's Alpha value of 0.93, indicating very high reliability. A total of 275 patients then completed the 27-item questionnaire, many also completing additional questionnaires on life satisfaction, depression, physical health and social desirability as well as psychophysical measures of tinnitus. This factor analysis also suggested three separate factors being involved; the physical, emotional and social consequences of tinnitus, the effects of tinnitus on hearing and the patient's view of their tinnitus.

The Tinnitus Reaction Questionnaire (TRQ) was designed by Wilson et al. (1991), specifically to measure psychological distress associated with tinnitus - evaluating the ability of the individual to cope with the condition. It is a 26-item questionnaire and was first given to 156 tinnitus sufferers, disagreeing with the above questionnaires in that it produced four factors labelled by the authors as: general distress, interference, severity and avoidance. Cronbach's Alpha coefficient was 0.96 and the test-retest correlation was 0.88. To assess validity, subsets of the patients were also tested on several psychological tests. The TRQ was found to be most strongly correlated with depression ($r = .63$) and with tinnitus annoyance ratings ($r = .72$; Henry, 1992). The TRQ was not found to hold any significant relationship with self-reported loudness, as would be expected. Correlations with audiological assessments of loudness (minimum masking level) were very small and failed to reach significance. Yet again, this concurs with the literature in that the "objective" severity of tinnitus is not significantly related to the level of distress, except perhaps when considering the very highest levels of loudness (Henry & Wilson, 1995).

The Tinnitus Cognitions Questionnaire (TCQ) was put forward by Wilson & Henry (1992), and included items designed to reflect positive and negative self-statements in relation to tinnitus such as "What did I do to deserve this?". A factor analysis of the TCQ (Henry, 1992) revealed that the scale is composed of three types of item: positive evaluations of tinnitus; hopelessness/despair; and helplessness/victimisation. The total score has been found to correlate significantly with the severity of depression as measured by Beck's Depression Inventory (r = .54; Henry 1992). Such findings are similar to those found in pain literature (Wilson, Henry & Nicholas, 1993). In a second study, they found that this emotional distress was associated with a set of beliefs that would be described by Ellis (1962) as irrational; namely such items as "It is unfair that I have to suffer with my noises" (p. 216) or "It will be dreadful if the noises never go away" (p. 219). Not all of these beliefs were related to distress, indicating a pattern of thought that is more than just negative response bias. An independent factor analysis (Henry, 1992) partially replicated the original results. Both an 'intrusiveness/persistence' factor and a 'communication/hearing problem' factor were identified, together with 'sleep difficulties' and 'emotional, mood and cognitive effects' factors. As with the pain literature, such results suggest that reactions to tinnitus vary along a number of distinct dimensions, complicating the nature of psychological adjustment to the tinnitus condition. Henry and Wilson (1995) also reported comparisons between subjects identified as 'good' or 'poor' copers based on their scores on the TRQ. Poor copers were found to have higher scores than good copers on both the BDI and the Tinnitus Cognitions Questionnaire, but not on a more general scale designed to measure engagement in automatic negative thoughts (the Automatic Thoughts Questionnaire; Hollon & Kendall, 1980). Thus, patients with difficulty in coping with tinnitus report engaging in a quite specific set of tinnitus-related cognitions.

In addition, Halford and Anderson (1991) created the Subjective Tinnitus Severity Scale (STSS), a 16-item questionnaire which aimed to estimate tinnitus severity in terms of such factors as intrusiveness, prominence and distress. It was originally tested on 112 members of a tinnitus self-help group. Reliability was established with a Cronbach's Alpha coefficient of 0.84. Validity was assessed with independent clinical ratings and psychophysical measures.

Table 1

*Summary of factors loading onto tinnitus questionnaires*

| Questionnaire | Number of Factors | Factor Name |
|---|---|---|
| Tinnitus Effects Questionnaire (TEQ) | 3 | Auditory perception difficulties; Emotional distress; Sleep disturbance |
| Tinnitus Handicap Questionnaire (THQ) | 3 | Effects of tinnitus on hearing; Patients view of tinnitus; Physical/emotional/social consequences of tinnitus |
| Tinnitus Reaction Questionnaire (TRQ) | 4 | Avoidance; General distress; Interference; Severity |
| Tinnitus Cognitions Questionnaire (TCQ) | 4 | Communication/hearing problems; Emotional/mood/cognitive aspects; Intrusiveness/Persistence; Sleep difficulties |
| Subjective Tinnitus Severity Scale (STSS) | 3 | Distress; Intrusiveness; Prominence |

As can be seen, different questionnaires court different aspects of the tinnitus phenomenon, though some commonalities are clear. Foremost is the concept of emotional distress. It is the lack of a relationship with objective severity that so strengthens the case for the more modern theories of Jastreboff (1996) and others.

## Theories of Tinnitus Generation

> "Specific dysfunctional cognitive processes of appraisal - such as catastrophizing and worrying - lead to negative emotional consequences, which in turn are worsened by maladaptive coping strategies."
>
> **Kröner-Herwig et al. (2000). Page 70.**

A number of potential mechanisms have been proposed to explain the process behind tinnitus generation (e.g. Tonndorf, 1987; Zenner & Ernst, 1993), most of which share some common features. These models were once restricted to consideration of auditory pathways alone - or more specifically, to the cochlea. In addition, these same models tended to focus solely on tinnitus generation, treating auditory pathways as passive transmitters of the signal to the auditory cortex. Consequently, diagnostic efforts were limited to psychoacoustical descriptions of tinnitus (i.e. loudness, pitch and maskability) while treatment consisted of attempts to attenuate to the generation of tinnitus at source. Unfortunately, as has been explained, psychoacoustical characteristics did not turn out to be of help in treatment or in prediction of outcome (Hazell et al., 1985). Further, they were unable to explain why people with the same audiograms may or may not have tinnitus, or why people with similar physical descriptions of tinnitus may differ radically in terms of irritation and the impact of the condition on their life. As such, the last ten years have seen a shift of emphasis from the otocentric (ear) concept of tinnitus to one placing far greater importance on the brain; both in generation of the tinnitus signal and in the generation of the distress that accompanies it. Nevertheless, in the majority of cases, the starting point of the disorder is still believed to be the cochlea. Yet it can arise in the auditory nerve and in the central auditory pathway - indicating that tinnitus can appear at all levels of the auditory system. For example, it has been suggested that tinnitus may be of peripheral origin when it can be acoustically masked and that the unmaskable variety is central in origin (Shulman, Tonndorf & Goldstein, 1985). Still, a disordered cochlea is likely to be the cause, and such a condition results in an alteration to the usual stream of work impulses going to the brain. This change in the signal can be detected and processed as if it were an actual sound (Baskill & Coles, 1999).

**Animal Models**

Objective signs of an animal model of tinnitus were first reported in guinea pigs (Evans, Wilson & Borerwe, 1981) and then cats (Schreiner & Snyder, 1987), both research groups using salicyates in doses large enough to produce blood concentrations known to invoke tinnitus in human beings. Evans et al. demonstrated that higher than normal spontaneous discharge rates take place in auditory nerve fibres of animals so affected. In turn, Schreiner and Snyder also observed an increase in spontaneous activity, with application of lidocaine reduces these salicyate-induced changes. Having said that, Møller (1984) was the first of several authors to imply that salicyate-induced tinnitus is not necessarily identical to tinnitus of other origins. As is well-known, there are a variety of mechanisms believed to be responsible for tinnitus, not all of them cochlear. Møller instead pointed out that in the absence of stimulation, spontaneous activity in cochlear-nerve fibres is uncorrelated (i.e. completely random). In low frequency fibres especially, the first sign of a response is by way of a grouping of discharges. Møller argued that these discharges are perceived as tinnitus. Central to his hypothesis is the assumption that tinnitus is associated with lesions of the auditory system, an opinion borne out by other authors (e.g. McFadden, 1982). In the majority of cases, tinnitus is a symptom accompanying hearing loss and profoundly deaf subjects usually suffer from louder - if not necessarily more distressing - tinnitus than those individuals without hearing loss (Graham, 1981). Arguing that the most frequent auditory system lesions concern hair cells, Tonndorf (1987) suggested 'ciliary dysfunction' can lead to tinnitus; in conjunction with hearing loss, recruitment and loss of speech perception - all symptoms of acute cochlear disorder.

During the 1980s, tinnitus research focused mainly on effective objective measurement. This was as work aiming to understand the underlying mechanisms of tinnitus generation and perception - thus providing treatment - was severely hampered by the fact that experimentation would have to involve human participants, with all of the obvious ethical constraints that would apply to such invasive procedures. Nevertheless, researchers were finally able to identify an animal model of tinnitus, thanks mainly to Jastreboff, Brennan, and Sasaki (1988; 1991) developing a behavioural method allowing observation of tinnitus in animals. The original proposal was made by Jastreboff and Sasaki (1986), an electrophysiological approach to develop a true animal model of tinnitus. This relies primarily on the conditioned response of the animal to silence, interfering with this reaction with massive salicyate, quinine or aspirin uptake, and producing the tinnitus sensation. Salicyate is well-known for its ability to provoke tinnitus in human beings with normal hearing, so Jastreboff (1996) was able to study animals with salicyate-induced tinnitus, showing increased spontaneous activity in the auditory nerve fibres, as well as abnormal patterns of activity in the inferior colliculus. Quinine - after salicyate - is the second drug of choice for inducing tinnitus. Importantly, it has been widely reported as being able to induce tinnitus in human beings without any other significant side-effect (McFadden, 1982; Rybak, 1986). For this reason, it was used by Jastreboff et al. (1991) to broaden the validity of their approach. While the perception of quinine-induced tinnitus is similar to that of salicyate (i.e. high-pitched, narrow band noise), the mechanism of quinine action is nevertheless different (Weir, Pasanen, & McFadden, 1988). Salicyate affects the cochlea, increasing the hearing threshold without modifying perception of higher intensity sounds (Puel, Bobbin, & Fallon, 1990). Alternatively, quinine affects cochlear transduction for all sounds, and it has been suggested that quinine acts through the alteration of cochlear blood flow (Rybak, 1986). As such, their underlying mechanisms of tinnitus generation are different, that they promote random and spontaneous activity in the auditory system in different ways, both of which are perceived as tinnitus. Accordingly, Jastreboff et al. (1991) sought to discover whether different forms of tinnitus nevertheless produce the same characteristic changes in behaviour. Their results support the notion that a true model of tinnitus should be indifferent to whichever particular mechanism induced it, whether salicyate or quinine or something else again. Quinine administration - and so presumably quinine-induced tinnitus - produced similar effects as those observed after salicyate (i.e. calcium channels were interrupted, affecting cochlea function). This methodology validated the observational approach, whereby attempts are made to introduce the animal to pathological conditions known to correlate with the presence of tinnitus (e.g. aspirin, noise exposure), and then search for changes in physiological parameters to identify the tinnitus sensation. In some situations, this has allowed observation of increased activity in auditory neurones; either electrophysiological (Jastreboff & Sasaki, 1986) or biochemical (Sasaki, Kauer, & Babitz, 1980). Such models help us to understand the physiological mechanisms of tinnitus as well as help to advance development and application of various treatments.

## Central or Peripheral?

The neural origins and mechanisms underlying tinnitus are largely unknown. The strong association between hearing loss, cochlear injury and tinnitus led to early speculation that tinnitus was due to abnormal discharges by the cochlea (Kiang, Moxon & Levine, 1970). This was refined to suggest three possible cochlear mechanisms for the production of tinnitus (Zenner & Ernst, 1993). However, other investigations noted the development of tinnitus after surgical transection of the auditory nerve. The persistence of the tinnitus signal after disconnection of the cochlea implies a central origin - at least in some cases (Jastreboff, 1990; Jastreboff & Hazell, 1993). Lockwood et al. (1998) also suggested that tinnitus arises in the central auditory system and not in the cochlea. They postulated that external tone bursts presented to just *one* cochlea produces bilateral activation of auditory cortical regions in both controls and tinnitus patients. However, when their patients altered the loudness of their tinnitus with facial movements - an ability reported by all participants in their study - *unilateral* not bilateral changes in cerebral blood flow were observed. This suggested to the researchers that a more central part of the auditory system - and not the cochlea - is the site of the spontaneous neural activity responsible. It is worth noting that these activation sites were confined to the hemisphere opposite to the ear with which patients reported their tinnitus sensation. Thus, the perceptual localisation of tinnitus to one ear would appear to be linked to activity of the opposite cerebral hemisphere. However, that is not absolutely certain. Lockwood et al. admit that while all other clinical manifestations of tinnitus (i.e. loudness, localisation, variability) corresponded with the stereotype, they chose participants for their ability to manipulate their tinnitus with facial movements, so this phenomenon could separate them from conventional tinnitus sufferers - reducing the value of any general comparison. Importantly, it was also fact that the authors "had no direct, independent method to verify the contention made by our patients that they have changed the loudness of their tinnitus" (p.118). Still, the cortical regions activated by external sounds were more extensive in the tinnitus sufferers than in the control sample. This expanded area of activation is consistent with observations in animals that demonstrate dramatic reorganisation of the auditory cortex after damage to high-frequency portions of the cochlea (Recanzone, Schreiner & Merzenich, 1993). Immediately after cochlear lesion, neural activity in the high-frequency portion of the auditory cortex is reduced. After several months of recovery, this region then becomes responsive to slightly lower frequencies. As a result, frequencies associated with normal hearing adjacent to the region of loss cause more widespread cortical activation than expected. This also happens in humans (Lockwood et al., 1998) but it is difficult to determine whether these changes are due to cochlea damage, tinnitus or a combination of the two.

Jastreboff (1990) proposed that abnormal activity within the auditory pathways is erroneously interpreted as sound by the auditory centres. As such, tinnitus generation would appear to originate in the cochlea and involve a dysfunction of the inner and outer hair cells. The consequence of this damage is altered information input. Jastreboff thus argued that the central nervous system compensates for a reduced signal by increasing the sensitivity of systems involved in processing auditory input. This abnormal neural activity is of "crucial significance" (Jastreboff, 1990; p.235) for the generation of tinnitus. Therefore, representation of tinnitus within the auditory system is much removed from the representation of external sounds. Jastreboff also attempted to explain the persistent nature of tinnitus, arguing that this abnormal pattern of activity is the reason why it is so much more difficult to suppress or habituate to tinnitus than it is to mask external sounds. Furthermore, although peripherally produced signals may fluctuate, the integrated manner in which fragments of the original pattern are processed leads to a perception of relative persistence. Persistence is also made more likely by attentional and orientation mechanisms being activated by new, ambiguous or anxiety-invoking information (Sokolov, 1963).

## Positive Feedback Loops

This suggested link between tinnitus and attentional processing is very plausible, and explains the arousal value of early tinnitus perception. However, it remains a little vague, and does not explain why tinnitus can be highly resistant to habituation and become an annoying disorder in some - though not all - individuals. If we include an emotional dimension, it becomes apparent that tinnitus is not regarded as a neutral perception. In fact, tinnitus is likely to be strongly associated with personal meanings and therefore be more than capable of possessing negative emotional valence. Jastreboff (1990) claims it is this which prevents early habituation. After all, tinnitus itself could be perceived as a threat; a cause for worry (e.g. the belief that it is merely the symptom of a much more serious illness such as a brain tumour), or as a cause for anxiety. The inexplicability of and the lack of control over tinnitus can be very stressful and may invoke constant, negative emotional responses. As such, Jastreboff assumes there are loops in the system, meaning that continuous sensory bombardment (tinnitus) is linked with significant emotions (concern, fear, and inability to control the situation), further amplifying the tinnitus signal through the creation of positive feedback. Jastreboff, Gray and Gold (1996) point out the powerful role the limbic system plays in this scenario. Yet, the concept of affective processes determining the persistence of attention to the tinnitus signal and the disruptive effects thereof, are not new. They are integral parts of concepts first mentioned by Hallam (1987) and Hallam et al. (1987) before being further embellished by Kröner-Herwig (1997).

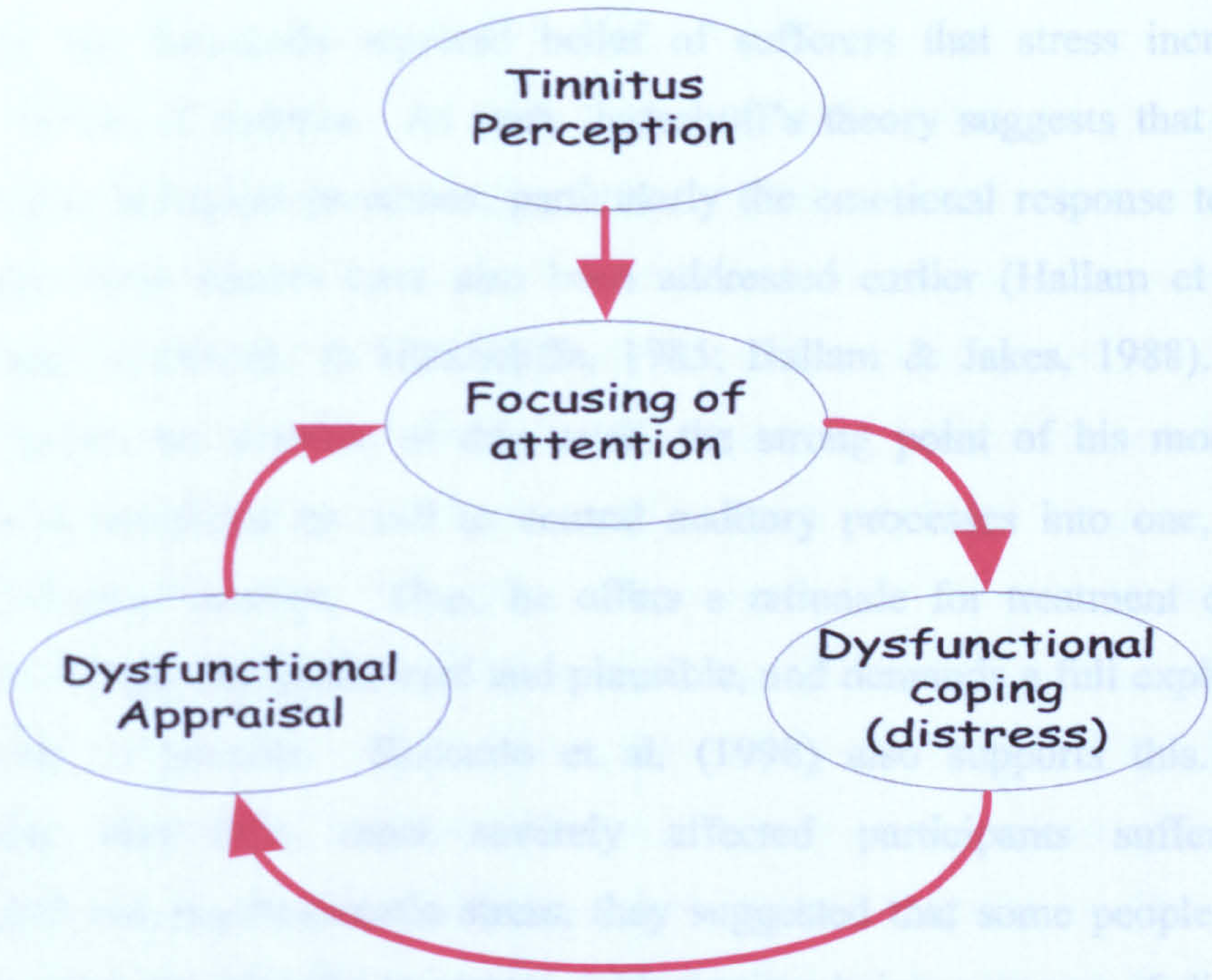



Figure 4: Psychological model showing tinnitus as the starting point for positive feedback loops (adapted from Kröner-Herwig et al., 2000).

This model, first developed by Hallam et al. (1987), can be seen in more advanced form in Figure 4. It shows a vicious circle in which different factors interact and create positive feedback loops, generating and maintaining tinnitus-related annoyance and discomfort. Tinnitus is viewed as an internal stressor on which the individual focuses attention. Specific dysfunctional cognitive processes of appraisal - such as catastrophizing and worrying - lead to negative emotional consequences, which in turn are worsened by maladaptive coping strategies. Furthermore, dysfunctional appraisal and attention tend to interact, keeping each other at a high level. These psychological processes augment the disability and the suffering attributed to tinnitus. Illness behaviour is developed, often based on avoidance learning (e.g. subjective justification of absenteeism from work when tinnitus hampers performance). These processes act together to ensure tinnitus is a stressor with disabling consequences. There is nothing groundbreaking in Jastreboff's proposals but he did relate these processes to actual neurophysiological structures (e.g. the limbic system). Further, Jastreboff (1996) claimed that a general pyschophysiological state of "non-verbal feelings of tension or discomfort" (Jastreboff, 1996; p. 502) unrelated to any evaluation can serve as a reinforcer, and may be a further cause of any lack of habituation. This is not something derived from psychological concepts but incorporates the frequently reported belief of sufferers that stress increases the disruptive effects of tinnitus. As such, Jastreboff's theory suggests that treatment focuses on psychological processes, particularly the emotional response to tinnitus. Nevertheless, these factors have also been addressed earlier (Hallam et al. 1984; Hallam, Jakes, Chambers & Hinchcliffe, 1985; Hallam & Jakes, 1988). Though Jastreboff makes no mention of this work, the strong point of his model is the integration of peripheral as well as central auditory processes into one, unifying, neurophysiological concept. Thus, he offers a rationale for treatment of tinnitus patients that is both straightforward and plausible, and demands a full explanation of the condition to patients. Rizzardo et al. (1998) also supports this. Having demonstrated that their most severely affected participants suffered great psychological and psychosomatic stress, they suggested that some people are more prone to reacting emotionally to events, with tinnitus being a source of distress that reinforces the symptom itself, accentuating distress and hypochondriac fear. On the other hand, others do not consciously acknowledge this distress, habituating somehow and not activating the vicious circle.

Both clinical observation and tinnitus assessment assert that attention may be the main cognitive mechanism underlying tinnitus annoyance and distress (Newman et al., 1997). The purpose of this system is orientation or attention, but in effect means that a novel internally-generated signal activates the same process as a novel external one (McKenna, 1997). As such, an indifferent and/or repeatedly presented stimulus is habituated to, and the strength of the behavioural response declines over time. Important stimuli (i.e. threats) maintain attention and so demand involvement of memory centres to relate the stimulus to previous experiences. In the case of tinnitus, it is suggested that the threat it poses to personal integrity (e.g. fear of tinnitus for the rest of the life, fear of potentially lethal disease causing tinnitus as a by-product) could lead to these mechanisms overriding the usual process. This ensures the survival of the signal, enhancing it further through the existence of negative beliefs held by the individual (Jastreboff, 1990, 1996; Sheldrake, Jastreboff, & Hazell, 1995). It is known that the prefrontal cortex and the limbic system control attention, memory and the emotional state (Chronister & Hardy, 1997; Tzourio, Massioui, Crivello, Joliot, Renault, & Mazoyer, 1997).

## Cortical Reorganization

Although many characteristics of tinnitus have been described in great detail, the mechanisms causing tinnitus have been poorly understood for many years, due to the lack of suitable techniques available to assess abnormal neural patterns in humans. However, recent advances in imaging techniques have made it possible to seek out cranial regions responsible for the production of transient, subjective sensations such as phantom limb pain and hallucinations (Flor et al., 1995). Tinnitus caused by cochlear lesions are belived to be the auditory equivalent of such conditions. For example, Lockwood et al. (1998) measured cerebral blood flow in four patients with cochlear hearing loss, all of with severe tinnitus localised to one ear. Significantly, all four patients possessed the unusual ability to exert substantial voluntary control over the loudness of their tinnitus by performing certain facial movements. These changes in loudness were associated with parallel changes in cerebral blood flow that were mapped by PET imaging techniques (Posner, Petersen, Fox, & Raichle, 1988).

Let us now reconsider the reports of close association between phantom limb pain and reorganization of the primary somatosensory cortex (Elbert et al., 1994; Flor et al., 1995). Mühlnickel, Elbert, Taub and Flor (1998) hypothesized that tinnitus might be a phantom phenomenon, one that could be proven by finding alterations of the tonotopic map in the auditory cortex of tinnitus sufferers. Ten right-handed tinnitus sufferers with maximum hearing loss of 25dB were compared with an equal number of right-handed controls with normal hearing and no tinnitus, matched for both age and gender. Any reorganization of the areas related to tinnitus frequencies may then lead to expansion of these areas into other sections of the tonotopic map, or even into adjacent cortical zones. With use of magnetic source imagery to measure invasion of the surrounding area, there was an increase of 5.3mm (SD = 3.1) into the contralateral hemisphere and 3.2mm (SD = 1.8) into the ipsilateral hemisphere. [Note: The entire tonotopic map of the auditory cortex normally extends 15mm medial-laterally]. In addition, the cortical map of tinnitus sufferers was rather distorted. It was possible to determine the relationship between tinnitus strength and the deviation of the tinnitus frequency areas of the tonotopic map, and the correlation between them was high for the contralateral hemisphere ($r$ = 0.82), but not ipsilaterally ($r$ = 0.15). There was an average hearing loss of 14dB in tinnitus sufferers as compared to controls, however this hearing loss did not correlate with degree of cortical reorganization ($r = -0.16$) or subjective tinnitus strength ($r = 0.09$). Clearly then, the tinnitus sensation is accompanied by a change in the tonotopic map of the auditory cortex. Furthermore, there is a significant positive association between subjective tinnitus strength and the expansion of the tinnitus frequency regions. This provides a striking parallel with the work by Flor et al. (1995) showing a strong correlation between levels of cortical reorganisation of somatosensory cortex and the level of phantom limb pain in upper extremity amputees. Importantly, both conditions involve puzzling aversive perceptual experiences that are not fully accounted for by the status of the peripheral structures of the body. It is therefore possible to put forward the claim that tinnitus is an auditory phantom phenomenon.

Future research may reveal whether tinnitus is maintained by cortical reorganisation or whether both are triggered by an unknown, common cause. Whatever the cause, the finding of a strong association between cortical reorganization and tinnitus opens the door to behavioural/pharmacological treatments that may be effective in future. For example, Recanzone et al. (1993) showed that auditory learning paradigms result in increasing representation of the frequencies involved. This suggests that a therapeutic approach with patients attending and discriminating acoustic stimuli close to tinnitus frequencies may drive cortical reorganization to counter the advance of the tinnitus region. Masking sounds have been used extensively without success (e.g. Feldmann, Lanarz, & von Wedel, 1992; cited Mühlnickel et al., 1998), but such noises were without true behavioural relevance. More successful treatment could involve use of noises adjacent to but not actually in the tinnitus range.

## The Neurophysiological Model

The neurophysiological model, as championed by Jastreboff, Grey, and Gold (1996), differs radically from the above in that tinnitus emerges as a result of the interaction of a number of subsystems. Auditory pathways play a role in the development and appearance of tinnitus as sound perception, whereas other systems - predominately the limbic system - are responsible for separate development of tinnitus annoyance. This manages to explain why psychoacoustical characteristics are only of secondary importance and have no bearing on treatment and outcome (Jastreboff, Hazell, & Graham, 1994). Furthermore, the model proposed by Jastreboff et al. stresses the importance of the basic principles of the nervous system, such as the capacity to become habituated to signals that are emotionally neutral and do not carry important information, and the fundamental basis of its design - plasticity.

Like phantom limb pain, the loudness and psychological impact of tinnitus may depend on the nature and extent of plastic transformations within the central auditory system. Although most tinnitus sufferers are able to adapt to the presence of phantom auditory sensations, many state that tinnitus causes severe disruptions to their daily lives (e.g. Hallam et al., 1984; Sullivan et al., 1988; Rizardo et al., 1998). As tinnitus loudness and other psychoacoustical characteristics of tinnitus do not correlate with measures of severity/distress, other factors must determine the emotional impact of tinnitus. Hallam, Rachman, and Hinchcliffe (1984) hypothesised that persistent or repeated high levels of arousal, or the attachment of affective significance to the sensation, impedes the development of tolerance to phantom sounds. Lockwood et al. (1998) put forward the idea that the neural systems mediating tinnitus may be linked to systems controlling emotions via the hippocampus, the portion of the limbic system that is the gateway to centres of emotional control, as well as being an important component of memory storage.

Auditory pathways, particularly towards the periphery, exhibit a high level of spontaneous and random activity that is not perceived as sound. On presentation of an external sound, activity increases, and more importantly, does so by way of an increase in synchronization among the relevant neurones (Møller, 1984). The auditory system constantly adjusts its threshold of detection depending on the level of external sound present. Notably, when placed in an environment with an extremely low level of sound, individuals hear the slightest noises (e.g. their own heart beat) and start to hear tinnitus within a few minutes. This increased sensitivity may be related to previous findings showing induced hearing loss - temporal or permanent - to result in increased sensitivity of the auditory neurones (Jastreboff, 1990; Gerken, 1993). It has been suggested that tinnitus occurs when signals previously treated as random, and so filtered out before processing, reach the level of awareness. When this deviation from randomness reaches a certain point, such activity is detected by subcortical centres and transferred to higher cortical areas where it is perceived as sound (i.e. tinnitus). In most people, this signal evokes an initial orientation reaction because of its novelty, but at this point is not associated with any form of fear-inducing or negative emotional state, nor is it interpreted as carrying a significant message, so the signal gradually undergoes habituation. That is, the individual in question is not aware of the presence of tinnitus except when consciously focusing attention on it, or when he or she is in a quiet environment, thus decreasing background-evoked activity and enhancing the perception of tinnitus. Even then, the tinnitus signal does not evoke annoyance and is treated as one of many background sounds. However, this situation changes dramatically when the initial perception of tinnitus is associated with negative emotions, induces fear/anxiety and begins to have qualities of threat. Typical examples of fears are: "I have a brain tumour; I am going deaf; I am going crazy; I will not be able to sleep; I will not be able to concentrate on my work so I'll lose my job; This sound will last forever and might even get louder" and so on (Jastreboff, Grey & Gold, 1996; page 237). While many people don't perceive tinnitus as threatening, they can become highly agitated due to its presence and by their lack of control over it. When this initially weak peripheral signal reaches the auditory cortex and results in tinnitus perception, the limbic system is activated, and the limbic system is concerned with the emotional association of sensory signals.

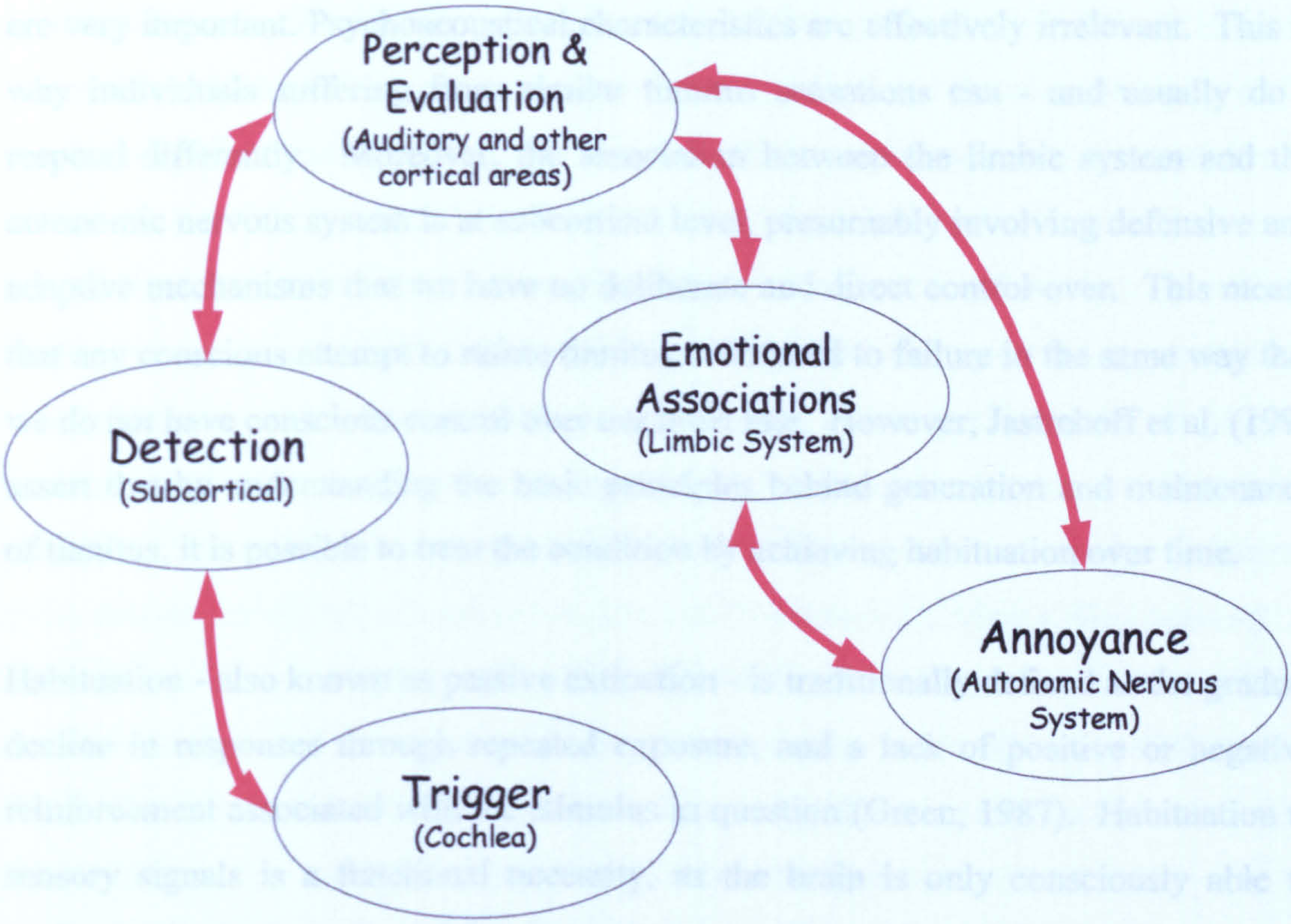



Figure 5: Stages of tinnitus development and centres of nervous system involved in determining annoyance level (adapted from Jastreboff, Grey & Gold, 1996).

As can be seen in Figure 5, the limbic system facilitates further detection and enhancement of the tinnitus signal, inducing activation of the autonomic nervous system to prepare the individual to respond to danger. This results in a feeling of annoyance. The autonomic nervous system is thus conditioned to respond to the tinnitus signal. Negative reinforcement accompanies conscious perception of tinnitus, strengthening the relationship between tinnitus and annoyance and increasing it further. As a result, a vicious circle is formed, with the presence of tinnitus activating negative associations and fears, which in turn, enhance the perception of tinnitus. Notably, the presence of negative reinforcement is believed to prevent habituation from occurring (Jastreboff, Grey, & Gold, 1996).

This model has its strengths in that it provides explanations for a number of the problems tinnitus poses. Firstly, since tinnitus annoyance is dependant on the limbic system, it must also depend on the subjective evaluation of tinnitus made by a particular sufferer. Therefore, associations between tinnitus and the emotional state are very important. Psychoacoustical characteristics are effectively irrelevant. This is why individuals suffering from similar tinnitus sensations can - and usually do - respond differently. Moreover, the association between the limbic system and the autonomic nervous system is at subcortical level, presumably involving defensive and adaptive mechanisms that we have no deliberate and direct control over. This means that any conscious attempt to refute tinnitus is doomed to failure in the same way that we do not have conscious control over our heart rate. However, Jastreboff et al. (1996) assert that by understanding the basic principles behind generation and maintenance of tinnitus, it is possible to treat the condition by achieving habituation over time.

Habituation - also known as passive extinction - is traditionally defined as the gradual decline in responses through repeated exposure, and a lack of positive or negative reinforcement associated with the stimulus in question (Green, 1987). Habituation to sensory signals is a functional necessity, as the brain is only consciously able to perform a limited number of functions at any one time. The situation is even worse when signals of the same modality are involved, for example: understanding conversation and listening to music. In ordering tasks to be performed, the brain uses the following principles: firstly, the importance of the signal, particularly if the signal is negative/threatening; and secondly, if it is novel. If a signal has not been associated with a specific event or if it is repeated over time, it gradually undergoes habituation and is no longer consciously perceived. Over time, it is even possible to become habituated to strong, albeit neutral, signals. Therefore, habituation can only be induced by removing the association between tinnitus and the emotional state - i.e. remove the activation of the limbic system through a combination of techniques (Jastreboff, Gray, & Gold, 1996). The authors opted specifically to educate patients on the potential causes of tinnitus. In most cases, tinnitus results from overcompensation to small, peripheral dysfunction. Jastreboff et al. presented sufferers with the results of their audiological tests in the belief that "known, even unpleasant, phenomena are less frightening than the unknown" (page 238). If the mechanisms behind tinnitus are understood, then it is possible that annoyance will decrease. As this occurs, the authors suggest repetitive, less intensive counselling may elimination negative associations originally evoked by the tinnitus sensation.

Tinnitus can only be subjectively assessed in humans, with invasive experimental methods inappropriate for clear ethical reasons. This makes it very difficult to study the neurophysiological mechanisms that underlie tinnitus. However, an early study on the surgical treatment of twenty tinnitus sufferers concerned the effect of frontal lobotomy, providing evidence for the role of the frontal lobe in the maintenance of severe tinnitus. After surgery, tinnitus distress declined in all patients, perceived loudness decreasing in half of them (Beard, 1965). Further support for aggravation of the tinnitus sensation by the cortex is provided in the surgical reports of patients undergoing treatment for acoustic neuroma. Post-operatively, the overwhelming majority of patients with pre-operative tinnitus continued to retain tinnitus sensation, even though the eighth cranial nerve was cut (Vanleeuwen, Meijer, Braspenning, & Cremers, 1996; Andersson, Kinnefors, Ekvall & Rask-Andersen, 1997). Other surgical invasions of the inner ear have given the same results (House, 1981; Sakai, Sato, Iida, Ogata, & Ishida, 1995). Thus, removal of the trigger/source of tinnitus in the periphery (e.g. cochlea, acoustic nerve) does not eliminate its perception.

Furthermore, Mirz et al. (1999) used positron emission tomography (PET) in a group of twelve tinnitus patients with severe tinnitus. Using masking techniques and lidocaine (to suppress tinnitus), Mirz et al. expected to isolate activation in the primary and associated auditory cortex, and the limbic system - supporting Jastreboff (1996). As it turned out, the majority of activated sites were in the right hemisphere; regardless of the ear in which tinnitus was perceived. This preponderance of the right hemisphere suggests a clear asymmetry in functional distribution, though as expected, specific areas of the prefrontal and temporal cortex were active prior to masking - but not during tinnitus-suppressive conditions. Thus, tinnitus is mediated by a specific network of linked neural areas. Though some differences emerged, Mirz et al. did agree with the earlier literature in that the sensation of tinnitus involves the auditory cortex, the limbic system and non-specific frontal brain regions. Tinnitus generation mediates emotional control and memory functions. A considerable reorganisation of auditory cortex occurs in parallel, explaining the expanded area of activation reported by Mühlnickel et al. (1998) and consistently seen in imaging studies. Thus, tinnitus is not the result of mere 'simple' auditory processing. Specific, higher order cognition is taking place, suggesting that tinnitus is indeed a potent force for distraction.

Intravenously administered, lidocaine causes temporary tinnitus relief in up to 80% of patients so treated (Mirz et al., 1999). Whether lidocaine acts on the cochlea, the auditory nerve or the cortex itself is not known (Merchant & Kirtane, 1986), but it is likely that lidocaine alters the tinnitus signal through inhibition of neurotransmission. Manabe, Yoshida, Saito, and Oka (1997) reported the inhibitory effect of lidocaine on the increased, salicyate-induced activity in the auditory nerves of guinea pigs. This is believed to be the neurophysiological equivalent of tinnitus in animals. Since animal studies involving salicyate are quite common, and usually show increased activity in more central regions (Wallhäusser-Franke, Braun, & Langer 1996; Wallhäusser-Franke, 1997), this points to a central network generating the tinnitus signal. On the basis of such results, Mirz et al. (1999) come out strongly in favour of a theory of central processing exacerbating the tinnitus sensation. This depends on the perception of aberrant auditory input, either spontaneous or pathological in nature. The signal is then modified because of prior auditory knowledge provided through the involvement of memory systems. Add to this the likelihood that tinnitus is associated with an inappropriate allocation of attentional resources and we have all the required fundamentals for a sustained state of alertness. Mirz et al. thus provide a consistent explanation that stands beside that of Jastreboff (1996) to explain the generation and maintenance of tinnitus distress.

## Evidence for Other Models

Yet, this is not the only hypothesis that has been considered. Though without the same experimental support, it has been speculated that tinnitus generation/perception may not be purely hierarchical (bottom-up; i.e. peripheral signal transmitted to the centre, causing perception and emotional response). It is possible that tinnitus could instead be created through spontaneous pathological interaction between areas of the brain that have nothing to do with auditory processing; i.e. top-down processing (Frith & Dolan, 1997). The auditory sensation itself may be secondary to the initial development of neurophysiological pathologies and cortical reorganization. Support for this hypothesis comes from Mühlnickel et al. (1998). This study clearly demonstrated that tinnitus is associated with a change in the tonotopic map, and that the auditory cortex undergoes reorganization in such circumstances. This has been observed in studies of cortical change through limb amputation and development of phantom limb pain (Elbert et al., 1994). Auditory cortices are activated alongside the right prefrontal areas associated with tinnitus - the auditory cortex in the right hemisphere is associated with pitch processing, and the right prefrontal lobe is associated with pitch retention for sound comparison (Zatorre & Samson, 1991; Zatorre. Evans, Meyer, & Gjedde, 1992). Activation of these areas may be responsible for the generation of a phantom signal perceived as tinnitus. Recently, a PET study comparing functional brain maps obtained during the process auditory hallucination found increased cortical blood flow in the auditory association cortex and anterior cingulate (Szechtman, Woody, Bowers, & Nahmais, 1998). Szechtman et al. suggest these areas are the sites specifically responsible for the production of auditory hallucination. Schizophrenia studies also report such activation under similar conditions (e.g. Frith, 1996; Woodruff et al., 1997). With regards to tinnitus sufferers, Mirz et al. (1999) hypothesize that the tinnitus sensation can, in some cases, emanate from pathological activation of subcortical systems without the need for stimulus from the cochlea or the auditory nerve. Therefore, tinnitus generation may be located centrally as well as peripherally. It is clear that perception, processing and interpretation take place centrally, and that tinnitus is associated with a linked series of cortical areas subservient to the auditory system. Severe tinnitus therefore represents a complete failure of habituation, where cranial regions normally interacting with the exterior environment maintain and attend to the tinnitus sensation.

## Tinnitus and Pain

> "Tinnitus, like chronic pain, is considered to be highly refractory to treatment and patients are generally told that they will have to learn to live with the problem."
>
> **Wilson, Henry, and Nicholas (1993). Page 192.**

Many researchers (e.g. Vernon & Meikle, 1985) have drawn attention to the similarities between tinnitus and chronic pain - though it should be remembered there is no equivalent tinnitus matching procedure as there is for the measurement of pain. Yet the comparison is valid as pain is also extremely subjective, and both affect and are affected by general mood states. The theoretical basis of much of the work in the area of chronic pain stems from the Gate Control model of Melzack and Wall (1965) which states that the experience of pain is determined by the interaction between sensory input and cognitive/emotional factors. Turk and Rudy (1986) likened this theory to a 'snapshot' (p. 762) of pain, suggesting a cognitive-behavioural model that took a long-term perspective, considering reciprocal interaction between variables, as well as potentially reinforcing effects over time. Research on arthritis - in which disease severity can be assessed - has suggested that psychological distress is completely unrelated to disease severity (e.g. Affleck, Tennen, Pfeiffer & Fifield, 1987; Flor & Turk, 1998; Smith, Peck, Milano & Ward, 1998), and this would also appear to be the case with tinnitus, with the distress caused unrelated to volume.

The definition of chronic pain is that it is not due to malignant disease, and has to have persisted longer than the expected recovery period (Bonica, 1977). In research, an arbitrary period of six months is taken as a means of operationally defining pain as being *chronic* (Black, 1975). Such pain can persist for many years, varying in severity and in the extent of associated dysfunction or disability (Volinn, Lai, McKinney, & Loesar, 1988). As well as the effect of disability on activities: e.g. work, home duties, leisure and interpersonal relations; chronic pain conditions are often associated with mood and sleep disturbances, long-term use of various medications (with associated side-effects) and high usage of medical services. It is also true that there is considerable variation in the degree to which people with chronic pain experience disability and distress (Wadell, Bircher, Finayson, & Main, 1984). Yet many chronic pain sufferers are able to maintain full employment (Taylor & Curran, 1985), most are not clinically depressed (Love, 1987), and many seem to manage without medication (Spanswick & Main, 1989). In large part, such individual variation has been attributed to psychological variables: such as reinforcement of maladaptive behaviour (Fordyce, 1976); poor coping strategies (Keefe, Crisson, Urban & Williams, 1990); and unhelpful cognitions (Rudy, Kerns & Turk, 1988); rather than actual pathophysiology. Obviously, psychological factors do not cause pain, but they do contribute to the development, awareness and maintenance of many of the problems associated with chronic pain.

The pain literature has sharpened understanding of what characterises good and poor coping, yet distress is often described without being defined. What, for example, determines who becomes a poor coper? Are coping skills acquired through life development, or are they more to do with the nature of the individual? Do people with low tolerance for pain and tinnitus have low tolerance levels to other aversive stimuli? These questions remain unanswered, with researchers of pain and tinnitus facing similar conceptual, practical and methodological difficulties in understanding and modifying distress in the face of chronic conditions. Yet the last decade has seen rapid development in cognitive interventions in both pain and tinnitus research. Research on coping with pain proceeds on the assumption that the aversive stimulus is a stressor which the individual needs to cope with, though this definition is often vague. Keefe, Salley, and Lefebvre (1992) state "One might expect that the pain experience is the primary stressor with which the pain patient must cope. In most patients, multiple stressors (e.g. loss of income, confinement, marital discord) are present and different sources of stress interact" (p. 131). Likewise, we can consider this in relation to tinnitus; and it is worth repeating that there are difficulties distinguishing between: the noise itself; other auditory problems such as hearing impairment and reduced redundancy; and other miscellaneous handicaps associated with the problem. It would, for example, be of tremendous use to know the extent to which environmental stress - independent of tinnitus - determines individual reaction.

Tonndorf (1987) was one of many to suggest an analogy between chronic tinnitus and chronic, intractable pain. Again, both are wholly subjective sensations. Both are continuous events, though with time, they may change in quality and/or character. Both can be masked by suitable inputs - though not in all cases. This includes masking of sound by pain and of dental pain by sound (Benjamin, 1958; cited Tonndorf, 1987). Pain signals are transmitted along somato-sensory pathways and tinnitus along auditory pathways. Both systems possess efferent fibres that exert some control over the input of the afferent fibres. In the classic 'gate control theory' of Melzack and Wall (1965), the relative balance between these fibres determines whether the pain sensation is triggered. The well-recognised time delay between impact and onset of pain can be explained in this way (Melzack & Melinkoff, 1974). Melzack and Melinkoff also discussed a possible mechanism for what they called residual inhibition - an auditory term (Tonndorf, 1987). Prolonged pain can produce permanent neural changes, such as formation of memory-like reverberating loops which may be interrupted temporarily by suppression techniques. These studies also indicate that suppression is more effective with pain of peripheral - not central - origin.

These principles are classic to the pain literature but it is not difficult to apply them to tinnitus, meaning that chronic tinnitus is, effectively, the auditory equivalent of chronic pain. Tinnitus is most common in profoundly deaf populations and in these cases it is very easy to account for the presence of tinnitus. Here, almost all hair cells are gone or badly damaged. Since auditory fibres also come in two opposing types (Tonndorf, 1987), chronic tinnitus likely to develop over time due to greater activity in the small-diameter auditory fibres. In addition, in most cochlear disorders, it is the outer hair cells that are most likely to be damaged due to their greater risk of exposure. Tinnitus is a very common symptom of such damage, with the small (inner) fibres acting largely unopposed by the larger (outer) ones, allowing the tinnitus sensation to be realised. Acoustical masking has a relatively short inhibitory effect, typically measured in minutes, and possibly reactivates the large-diameter fibres in the same way as scratching reactivates pain fibres. This is supported by the fact that masking is only effective in the case of peripheral tinnitus (Shulman, Tonndorf, & Goldstein, 1985), whereas drugs can act peripherally or centrally. As with pain, tinnitus is easier to suppress when peripheral, though it is often under central control, as anxiety and lack of sleep would appear to aggravate it while distraction alleviates it.

Wilson, Henry and Nicholas (1993) provided a useful overview to assist in the understanding and management of tinnitus and chronic pain. They have much in common, not least of which is that they manifest for many years. Numerous medical treatments have been employed for both, though treatments are only effective in a small proportion of cases (Wilson et al., 1993). Both share numerous consequences: reduced employment; interpersonal problems; and decreased opportunities to engage in enjoyable activities. There is little external manifestation of the problem, usually resulting in reports by patients that other people do not understand them or that they have been accused of malingering. For chronic pain and tinnitus, there is a complex set of relationships between individual perception of the aversive stimulus (pain or noise) and the psychological distress experienced by the sufferer.

Tinnitus has been linked to craniomandibular disorder (CMD) in scientific journals from as long ago as 1934. Costen (1934; cited in Erlandsson et al., 1991) included tinnitus in what was referred to as 'a syndrome of ear and sinus symptoms dependent upon disturbed function of the temporomandibular joint (TMJ)' (page 16). Several authors (Morgan, 1975; Bush, 1987; Rubenstein & Carlsson, 1987) have shown that treatment of CMD often reduces tinnitus levels. Using 42 tinnitus sufferers with self-reported CMD symptoms and 30 without, Erlandsson, Rubinstein, Carlsson and Ringdahl (1987a) split their sample into three different mood groups. They demonstrated that both state and trait anxiety were significantly higher in the low mood group than in the medium and higher ones. There was a predominance of noise-induced hearing loss and left-sided tinnitus in the low mood group, and it was noted that none of them had normal hearing. However, keeping in mind that CMD symptoms are found in a majority of tinnitus patients (Rubenstein & Erlandsson, 1991), Erlandsson et al. reported no difference in tinnitus characteristics between those with CMD and those without. Self-ratings of tinnitus intensity correlated negatively with mood but not state anxiety. This agrees with the pain literature, where such anxiety measurements have only ever been weakly associated with pain intensity. For example, Garron & Leavitt (1983) linked trait anxiety - but not state anxiety - to chronic pain intensity.

The relationship between mood and pain has been studied in detail. Shacham, Reinhardt, Raubertas, and Cleeland (1983) stated that pain and mood states are associated. This is thought to be important to tinnitus research. Since it is believed that some relationship must exist between tinnitus intensity and annoyance/distress, observations of intensity and mood are relevant. According to Persson and Sjoberg (1987), painful rheumatoid arthritis symptoms are less associated with mood than they are with symptoms. However, chronic arthritis is more clearly understood than tinnitus. Furthermore, effective rehabilitation programs for rheumatoid arthritis exist, whereas most tinnitus sufferers have not experienced relief through treatment. Patients with noise-induced hearing loss are clearly aware of the cause of their tinnitus (i.e. ear trauma), so it would be expected that they would worry less about where their tinnitus has come from. In spite of this reasoning, tinnitus sufferers predominated in the low mood group of Erlandsson et al. (1991). The authors suggest that since these tinnitus sufferers were almost exclusively men, they may have been exposed to noise while working in noisy industrial environments, and since this type of hearing loss is technically difficult to rehabilitate, there was limited success in adapting to hearing aids. Hearing difficulties in social settings clearly cause problems, but Erlandsson et al. suggest displayed distress is due to tinnitus, not impaired hearing, a point raised again by Meric et al. (1998). If patients with hearing loss do become socially and emotionally handicapped, it is not down to the degree of their hearing loss, but rather to rehabilitation available - and environmental conditions. Further, the effects of being less capable to work prior to normal retirement should be considered.

The diathesis-stress model was originally developed in research on schizophrenia. More recently, it was suggested as a heuristic model for understanding high rates of depression in chronic pain patients (Banks & Kerns, 1996). Since similarities between tinnitus and chronic pain have already been discussed (Tonndorf, 1987; Wilson et al., 1993), there is no point in reiterating these arguments. However, research on the psychological aspects of pain is well ahead of similar tinnitus research, so it is useful to apply the stress-diathesis model here. Theoretically, it is compatible with the habituation model of Hallam et al. (1984) and the neurophysiological model of Jastreboff and Hazell (1993). Given that tinnitus is a significant stressor, it is not surprising that different people react differently. This reaction depends on numerous factors, not least of which is vulnerability to stress. The models of Jastreboff and

Hazell emphasize the importance of central processing, not peripheral factors. As such, perception of tinnitus is determined by interaction between a peripherally generated signal and psychological factors which vary according to the individual. Therefore, successful treatment must take into account audiological and psychological assessment to determine the most beneficial approach. Many people only encounter tinnitus for a temporary duration - yet after six months, spontaneous remission is unheard of, the tinnitus now permanent (Wise, Rief, & Goebel, 1998). Under such conditions, some tinnitus sufferers succumb to psychological side-effects, with treatment increasingly necessary. Ross, Echevarria, and Robinson (1991) reported eight major non-pharmacological treatment options for patients with tinnitus: reassurance; hearing aids; maskers; tinnitus instruments; environmental masking; cochlear implants; refusal of treatment; and miscellaneous therapies - including counselling, biofeedback, ear plugs and physiotherapy. Further, treatment for depression is essential.

## Tinnitus and Masking

Masking uses external sound to obscure the internal noise of tinnitus (Vernon, 1991). A simple example of masking could be a radio tuned between stations and so emitting a background noise, or an electric fan in the background. Many sufferers are most irritated at night by the continuous ringing or buzzing of their tinnitus. It is well-established that an external stimulus - e.g. white noise - can mask tinnitus in some cases (Feldmann, 1971; Vernon, 1977). However, though sophisticated tinnitus maskers are available, they are of little use to hearing aid wearers who remove their only means of hearing before sleep. A number of reviews are available on the fitting of tinnitus maskers (Hazell et al., 1985; Sheldrake, Wood & Cooper, 1985; Coles, 1987) but interestingly, there is no way to determine whether a patient will benefit from masking without trying it first. The tinnitus sensation need not be completely masked for effective treatment and many patients are satisfied with partial masking (Tyler, Aran & Dauman, 1992). However, the number of people benefiting from tinnitus masking is more controversial. High success rates have been reported (Hazell et al., 1985; Shulman & Goldstein, 1987), but most have been less optimistic (Stephens & Corcoran, 1985; Wilson, Henry, Andersson, Lindberg, & Hallam, 1998).

Minimal Masking Level (MML) of tinnitus has received increased attention in recent years as a possible predictor of acceptance of tinnitus masking treatment, and also as a measure of treatment success (Vernon, Griest & Press, 1990; Jastreboff, Hazell, & Graham, 1994). Stress caused by tinnitus is likely to be worse for those tending towards depression, so it was hypothesized by Andersson and McKenna (1998) that a negative relationship exists between MML required and patient depression. In other words, patients with more depressive symptomatology will have lower MML, implying that their tinnitus is not as loud as in others, but that this is mediated by a tendency to focus on internal sensations. After all, lower sensitivity to environmental sound has been observed in depressed individuals (Malone & Hemsley, 1977), as well as increased self-focus and decreased tolerance to pain (Banks & Kerns, 1996). Andersson and McKenna found a relationship between BDI scores and MML, though this relationship was not linear. Discovering three distinct clusters of tinnitus sufferers, Andersson and McKenna proposed a curvilinear relationship, whereby minimal masking level is moderated by depression levels in the tinnitus sufferer.

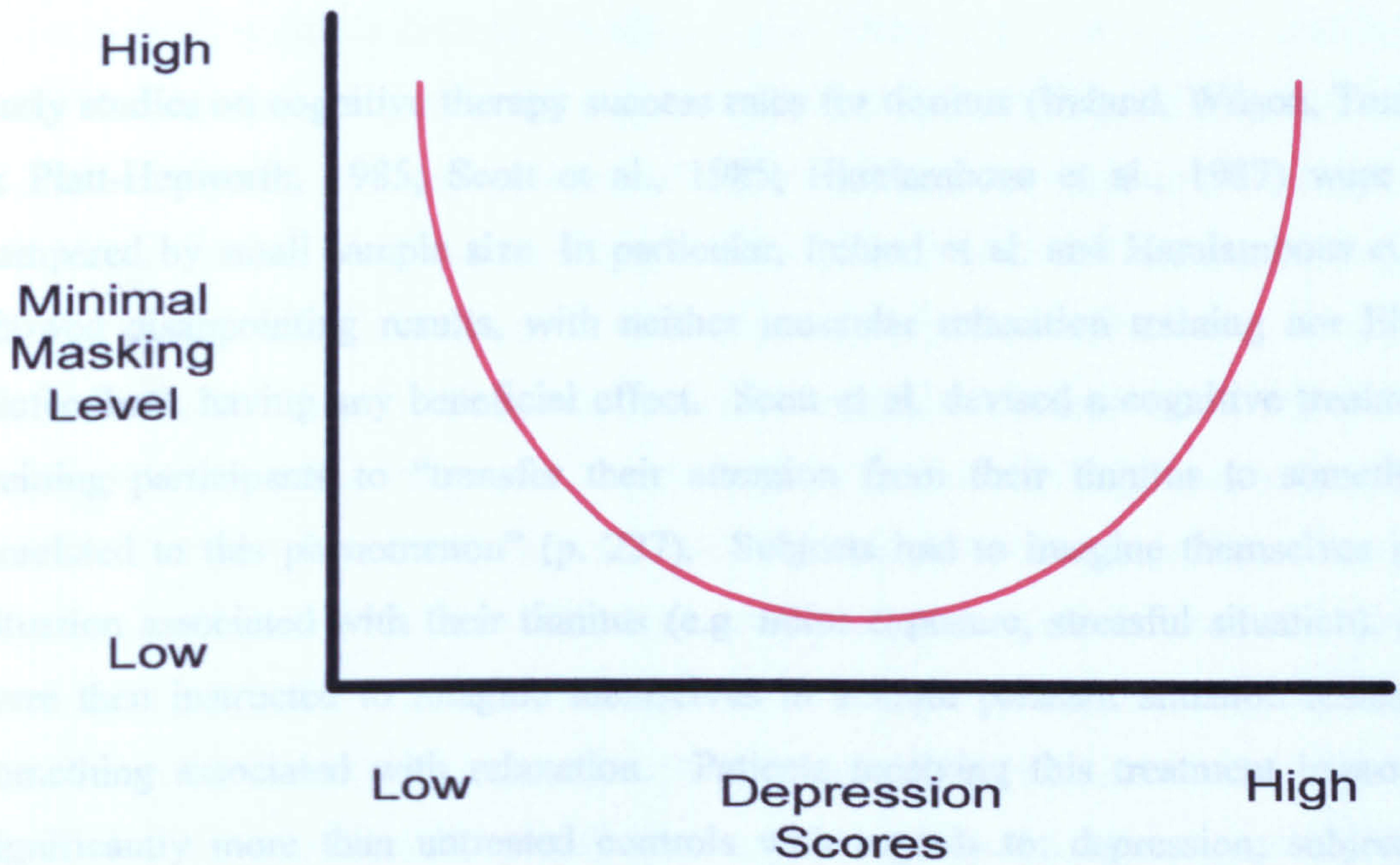



Figure 6: Curvilinear relationship between minimum masking level (MML) and the depression scores of tinnitus sufferers (Andersson & McKenna, 1998).

Figure 6 incorporates the vulnerability of the person and the significance of the stressor (i.e. tinnitus). Andersson and McKenna (1998) reported BDI scores similar to those reported by other researchers (Kearney, Wilson, & Haralambous, 1987; Henry and Wilson, 1995). In other words, their clinical sample was suffering from dysphoria - mild depression - as defined by Kendell, Hollon, Beck, Hamman, and Ingram (1987). In addition, loudness measurements appeared higher than normal, but not unusually so. However, Andersson and McKenna only included patients suffering from severe tinnitus and this may go some way towards explaining the difference between this and other studies (e.g. Tyler & Stouffer, 1989). As ever, no correlation was found between loudness and distress. The finding of three clusters of patients, may be very helpful to further research, and the idea of a moderated relationship has important implications for deciding which treatments may or may not be effective. Treatments targeting the depressive aspects of tinnitus may be very effective in certain conditions but, as can be seen, Andersson and McKenna (1998) suggest that many tinnitus sufferers show limited signs of depression.

## Tinnitus and Cognitive Therapy

Early studies on cognitive therapy success rates for tinnitus (Ireland, Wilson, Tonkin & Platt-Hepworth, 1985; Scott et al., 1985; Haralambous et al., 1987) were all hampered by small sample size. In particular, Ireland et al. and Haralambous et al. showed disappointing results, with neither muscular relaxation training nor EMG biofeedback having any beneficial effect. Scott et al. devised a cognitive treatment training participants to "transfer their attention from their tinnitus to something unrelated to this phenomenon" (p. 227). Subjects had to imagine themselves in a situation associated with their tinnitus (e.g. noise exposure, stressful situation), and were then instructed to imagine themselves in a more pleasant situation instead - something associated with relaxation. Patients receiving this treatment improved significantly more than untreated controls with regards to: depression; subjective tinnitus loudness; and tinnitus discomfort - but not on objective audiological measures. These effects were maintained at a nine month follow-up study (Lindberg, Scott, Melin & Lyttkens, 1987). In a further study, Lindberg et al. (1988) reported on the overall outcome of cognitive behavioural therapy in the clinical treatment of a large sample of 75 patients. Treatment included: information; behavioural analysis; relaxation training; and cognitive techniques. Overall, discomfort ratings decreased and mood improved over time. At three month follow-up, 75% of subjects reported improvement, whereas 24% noticed no effect and 1% reported marked deterioration. Unfortunately, there was no control group to compare these results with, making it much harder to ascertain the contribution made by treatment. In general, Lindberg et al. (1987, 1988) claim short term success but state that clinically, gains were modest.

These studies hold a central theme in common - namely a single cognitive component (i.e. attentional diversion or imagery training) similar to the methods used in pain management. An alternative approach involves explicit examination and modification of thoughts and beliefs held about tinnitus. This approach is based on the cognitive restructuring method advocated by Beck, Rush, Shaw, & Emery (1979) in self-management of anxiety and depression. Cognitive theorists like Beck argue that the source of distress is not tinnitus itself but rather the way in which tinnitus is thought of. For example, the tinnitus sufferer may have positive thoughts such as: "The noise won't hurt me", "It has been as bad as this before but it generally gets better after a while," or "If I do something enjoyable, I probably won't notice it as much". Alternatively, negative thoughts could prevail: "How can I live my life with this noise?", "This noise is making my nerves worse" or "This is the worst thing that can happen to anyone". Cognitive therapy begins with detailed analysis of the kinds of self-statements that people engage in when they ponder their tinnitus, especially when the tinnitus is particularly severe or when they are at their most distressed. Cognitive restructuring develops skills to stop negative thoughts, instead substituting more appropriate and constructive ones. Application to tinnitus was suggested by Sweetow (1984, 1986) but we had to wait for Wilson, Bowen and Farag (1992) before any results were reported. In their first study, Wilson et al. randomly allocated tinnitus patients to one of three conditions: cognitive therapy; relaxation training; or waiting list control. Treatment consisted of weekly sessions over four weeks, three delivered in small group format, and one individual session. Subjects in the cognitive therapy and relaxation training groups then received the alternative treatment (phase two). Assessments were conducted at pre-treatment, mid-treatment (between the change from one treatment to the other), and post-treatment, alongside daily ratings of tinnitus annoyance. Both treatments reduced tinnitus annoyance, the positive effects increasing when both treatments had been applied together. Henry & Wilson (1996) compared cognitive-educational therapy with an education-only programme and a waiting-list control condition. The combined treatment was again found to be superior, producing the greatest reduction in tinnitus-related distress (TRQ) and dysfunctional cognition (TCQ). This supports the efficacy of a duel approach, suggesting that non-specific treatments are unlikely to aid tinnitus management, and that the improvements were specifically down to the interventions described. Education may lead tinnitus sufferers to utilise coping strategies, but it would appear that such strategies do not benefit people without cognitive therapy running in parallel. The authors also state that the magnitude of clinical effects are slight. For example, post-treatment TRQ averages remained near/at the criterion for entry into the study. In addition, the 12-month follow-up suggested that effects are not maintained over time. Thus, while a combined approach is beneficial, gains remain modest. Such results may appear disappointing, but do help identify the most promising components, highlighting where improvements and refinements could be made. Furthermore, longer treatment and additional therapeutic components have been successful in managing chronic pain (Nicholas, Wilson, & Goyen; 1991, 1992).

Tinnitus Management Therapy (TMT) is an example of a process seeking to enhance the patient's model of his/her disorder, addressing issues which inhibit tinnitus habituation, without referring to them as problematic. Use of cognitive strategies, attention diversion and promotion of a healthy lifestyle spearheads the attempt to reducing the importance given to tinnitus, indirectly reducing the annoyance it causes. Wise et al. (1998) compared a tinnitus treatment program with a non-specific problem-solving group therapy to see which was more effective in alleviating distress. However, the authors point out a weakness in their own study, that tinnitus patients referred to a psychosomatic clinic may have more psychological problems than out-patients and, therefore, benefit more from a problem-solving group anyway. Furthermore, patients in both groups also received additional therapies including relaxation techniques, assertiveness skills training and individual therapy, which may have affected outcome. Moreover, no follow-up evaluation took place. Yet the authors still reported more satisfaction with the tinnitus-specific treatment. Interestingly, these patients also reported that they were better at dealing with problems. Another unexpected result was that older patients in the TMT group gained more than their younger counterparts. It would seem a standardised program aimed explicitly at dealing with a somatic problem is well-received by all tinnitus patients, but especially those over 50 years of age. This is important as roughly a third of all people over the age of 65 are afflicted with tinnitus (Sataloff, Sataloff & Lueneburg, 1987). While the Tinnitus Effects Questionnaire (TEQ) did not show either group to improve significantly more than the other, TMT was believed to be more helpful in general and was rated significantly higher as the 'proper' treatment. The patients involved felt that they were better understood and that they were being taken more seriously. Also, the proportion of participants completing treatment was higher in the TMT group. This suggests that TMT fulfils the need for adequate counselling, as recommended by Jastreboff (1996).

Many medical treatments have failed to help with chronic tinnitus, including the latest ideas, such as hyperbaric oxygenation, which are often administered to patients even though they don't work (Lutz, 1998). As such, demands for new therapies continue and a number of publications designate tinnitus retraining therapy (TRT) as a breakthrough in treatment techniques, boasting a success rate of 80%. Due to its increasing popularity, Kröner-Herwig et al. (2000) set about a more critical analysis which will be discussed in due course. Unifying the work of both Jastreboff (1996) and Hallam et al. (1984, 1987), many treatments developed in the last fifteen years emphasize the roles of interventions aimed at modifying the crucial factors mentioned in Figure 4 (page 49). Such psychological interventions - multi-modal strategies in particular - have recently demonstrated some success in decreasing tinnitus-related disability, reducing the disruptive consequences of tinnitus (Kröner-Herwig et al., 2000). Counselling is therefore the most important treatment component, since habituation to tinnitus cannot be reached without segregating the emotional response from the experience of tinnitus (Jastreboff, 1996). TRT does not reduce general arousal, tension or discomfort, though Jastreboff states that discomfort is a factor in any failure to habituate. Nevertheless, the primary objective of TRT is to induce psychological change into the cognitive-emotional processing of noises not anchored in the physical world, an objective shared by many others (Goebel, Hiller, Fruhauf, & Fichter,1992a; Henry & Wilson, 1992; Kröner-Herwig, Esser, Frenzel, Fritche, & Schilkowsky, 1999). It focuses on several factors: cognitive restructuring (i.e. disassociation of negative emotional association); attentional direction processes (i.e. to direct attention to competing inner and outer events, auditory or not); stress management (i.e. reduction of stress-related arousal); coping with tinnitus (e.g. systematically enriching sounds in the environment); and modifying avoidance behaviour motivated by tinnitus (e.g. increasing social contact). The latter is vital and, as pointed out by Kröner-Herwig et al. (2000), is neglected in Jastreboff's model.

Tinnitus masking is of real importance to TRT. Noise generators attempt to dissociate negative affect by temporarily drowning out the tinnitus sensation, and it is recommended that patients are supplied with additional external sounds to distract the hypersensitive auditory system of the sufferer. Patients are thus advised to use noise generators below masking for months or even years at a time. Bilateral use is strongly recommended, but not theoretically substantiated (Kröner-Herwig et al., 2000). It is argued that the habituation process can be facilitated by increasing the richness and variety of sounds available (e.g. listening to music) or though the proper use of hearing aids to amplify background noise comfortably. However, Jastreboff states that sound will not be effective if the disassociation of negative emotion is unsuccessful. Use of noise generators retrains the higher processing centres. This involves a gradual reorganisation of the cortical areas which recognise tinnitus and, in particular, its interaction with the emotional state. This concept was taken further by Mühlnickel et al. (1998), and it is becoming apparent that focusing on tinnitus frequencies is not as effective as focusing on those surrounding them. This is a central, not a peripheral, process and one aimed at facilitating tinnitus habituation.

Jastreboff and Hazell (1993) emphasize that TRT only reduces negative impact. Patients are educated about the auditory system and about how tinnitus is thought to work. The principle is that the patient must understand the basis of the approach and what can be expected from it (Grey, Jastreboff & Gold, 1996). It is emphasized that tinnitus is nothing to worry about, and that it is the worrying that keeps the tinnitus alive - preventing habituation. Noise generators are usually recommended for six to eight hours a day, adapted for individual use. Whether further counselling sessions are held is up to the patient. Yet Kröner-Herwig et al. (2000) remain critical. In their clinical experience, chronic tinnitus sufferers need sophisticated intervention programs to change tinnitus-related cognitions, emotions and behaviour. They argue that TRT does not have an established protocol, with different centres handling treatment in different ways. In addition, information gathered from interview is vulnerable to the influence of social desirability; it is difficult for a patient to renounce a therapeutic progress when face-to-face with a dedicated therapist. Furthermore, self-reported data is collected in a manner lacking methodological quality. "The questions are global, sometimes hard to understand" (Kröner-Herwig et al., 2000; p.72). The use of a tinnitus diary is rejected by Jastreboff, though it has been observed that the process of keeping a dairy can, in itself, be therapeutic in reducing annoyance (Kröner-Herwig et al., 1995). Moreover, diaries are advantageous in that the experience and behaviour of the sufferer can be assessed not only in the everyday environment but also without time delay, thus limiting memory biases in self-report.

From 600 patients at a TRT treatment centre, Jastreboff (1996) randomly selected 124 and evaluated improvement. Two groups were created, one receiving full treatment including masker and follow-up visits, with the other having a single counselling session - though the existence of the latter is not explained in detail. Improvement was defined by specific criteria: that tinnitus-related interference of at least one activity had ceased; that time aware of tinnitus was reduced by 30%; that annoyance of tinnitus was reduced by 30%; and that the patient confirmed that their tinnitus had improved. Jastreboff found that 79.4% of the patients given the full program had improved compared to only 18.2% of those having a single counselling session. However, varying levels of tinnitus severity were not reported, and no control group was used. Kröner-Herwig et al. (2000) were very critical, stating it was characterised by "various methodological weaknesses" (p. 73) and could not claim to be a rigorous test of the usefulness of such therapeutic methods. Vesterager (1994) published a study of 181 patients taking part in a program providing supportive psychological therapy and instrumental treatment - noise generators and hearing aids. The sample consisted only of patients with severe tinnitus, reporting the condition as being bad enough to interfere with daily activities and life in general. Three standard sessions providing information, therapy and equipment took place with an outcome evaluation carried out over a year after the last therapeutic contact. These indicated that 1/3 of patients returned their instruments within six months, with only 16% using their noise generator/hearing aid daily. After therapy, tinnitus loudness was seen to decrease, easing concentration and sleeping problems. However, as is often the case, no control group was used and the evaluation/treatment processes were not adequately described. McKinney, Hazell, & Graham (1999) evaluated a variant of TRT, assessing patients at 6, 12 and 24 month periods afterwards. Criteria for success were set at a 40% improvement in at least two of the following: annoyance, life quality, awareness and loudness. No psychometrically validated tests were used but on the whole, it appears that greatest improvement occurs after 3-6 months. After six months, only slight improvement was found, suggesting that the need for extended therapy does not exist. Differences in the level of minimal masking used were not significant. It could therefore be suggested that the counselling element of TRT is the most important single aspect and that gain from wearing any sort of instrument is minimal. In this vein, Sheldrake et al. (1996) reported on 149 patients treated by way of TRT in a clinical trial lacking a control group. They state an improvement of 96%, a claim derived mainly from interview data on tinnitus awareness. Wilson, Henry, Anderson, Lindberg & Hallam (1998) are critical of this study due to lack of clarity regarding measurement procedures and the definition of improvement. Therefore, these highly positive results are in doubt.

Von Wedel et al. (1997; cited Kröner-Herwig et al., 2000) compared the benefits of partial and complete masking, though their analysis was retrospective. Partial masking appeared to be the most effective - as measured by questionnaires. The authors estimated that after 3 years in the total masking condition, complete relief from tinnitus was reached by 7-8% of patients, with partial relief achieved by 25% of hearing aid users and 16% of noise device users. Having said that, the criteria of 'partial relief' was quite hard, namely a 10-point drop in scores on the Tinnitus Effect Questionnaire (Hallam et al, 1988). In the partial condition, total relief was reported by 38-41% of sufferers, with another 38% experiencing partial relief. This supports Jastreboff (1996) in that total tinnitus masking is not helpful. However - yet again - no control group was used, so all these studies are unable to answer the important question of whether the development of patients receiving treatment differs from the development of the condition in sufferers not receiving treatment. Could this, in fact, merely be the process of habituation? It is impossible to say.

## Summary

Originally, the word 'stress' was an engineering term borrowed by psychologists. Broadly, it can be defined as wear and tear on the body, and can be brought about by environmental pressure, physical difficulties and psychological conflict, and theories can explain the extensive effects of stress on the human body (Faye, Heng, Collomp, & Peroux, 2003). Constant pressure from the various causes of stress can cause the individual to be constantly prepared for action, resulting in physical disorders over the long-term. Tinnitus *is* a stressful experience. In addition, some patient histories have suggested that stress causes the original onset of tinnitus (House, 1981). Simply put, patients who suddenly begin to hear noises in their head generate stress about the meanings behind these strange and constant sounds. Individual attitudes help to determine thresholds for pain and disturbance and it is the same for the tinnitus sensation. Like pain, tinnitus draws attention towards the affected region and if this concern is not relieved, patients are prone to suffer further as a result of their worry over what these new noises represent. Appropriate medical testing and concern can restore individual confidence and, in many cases, tinnitus diagnosis reveals that there is nothing to be concerned about. At this point, many tinnitus sufferers stop worrying and the stress is relieved. However, patients need an explanation of their problem and encouragement about the future. Without this, the tinnitus will remain problematic.

In conclusion, Kröner-Herwig et al. (2000) believe TRT (counselling in particular) may help many tinnitus sufferers, but certainly not all of them. In addition, they maintained that the educational aspect is merely the first stage of treatment. They did not question the need for noise generators per se, but suggest that success utilising them may be due to them being some sort of technical placebo. As psychologists, they also wonder why Jastreboff did not include interventions to reduce stress and tension due to the importance ascribed to stress in his own model. Moreover, many of the research papers investigating TRT lack methodological quality, and only a few studies (e.g. Biesinger et al.,1998; cited Kröner-Herwig et al., 2000) have made use of psychometrically valid tests as outcome measures. Control group comparison studies have also been lacking. Nevertheless, Jastreboff, Gray & Gold (1996) state that habituation through directive counselling is an essential step in treatment of tinnitus. Counselling allows for the disassociation of the reaction to tinnitus (i.e. annoyance), promoting smaller and smaller effects. Jastreboff et al. suggest enhancing the level of auditory background surrounding the patient, particularly if counselling takes place in quiet surroundings, so increasing background levels of spontaneous activity in the auditory pathways. In contrast, this will reduce the overall effect of the tinnitus sensation, making the process of detecting it though the background activity much more difficult, and facilitating habituation. In summary, the neurophysiological approach is aimed at inducing and facilitating habituation. It is not a cure, nevertheless, it is an attempt to reduce annoyance, thus removing the mainstay of the negative impact on the individual concerned. To date, treatments for tinnitus have varied widely, ranging from: simple reassurance; hearing aids; use of acoustical maskers; transdermal electrical stimulation; and drugs; discounting more overt psychological methods such as biofeedback and hypnosis. Such a large number of treatments suggests none are particularly effective. Further, tinnitus often coexists with other conditions, major depression being just one. Møller (1997) notes the sheer heterogeneity in the tinnitus population, the implication being that there is individual variability in aetiology, mechanisms, and most certainly within the boundaries of individual experience. This variability is so great, it seems almost impossible that a single agent could, by itself, bring about an improvement in tinnitus for everyone. As such, any single-pronged treatment technique must be doomed to failure.

Recent research has advanced knowledge of tinnitus sufficiently to merit a more optimistic view of the future. Most important has been the realisation that persistent, troublesome tinnitus involves central nervous system changes rather than simple cochleae pathology - through publication of neuro-physiological (Kaltenbach & McCaslin, 1996; Eggermont, 2000) and neuro-imaging (e.g. Lockwood et al, 1998; Mülnickel et al., 1998; Mirz et al., 1999; Salvi, Lockwood, & Burkard, 2000) studies. With the advent of hair cell loss in the cochlea - or some other change in the periphery - areas of the brain now devoid of sensory perception may reorganise in a way that strikes parallels between tinnitus sufferers and phantom limb patients (Flor et al., 1995). This reorganization consists of fibre growth, extension and the development of new synaptic connections, usually involving auditory fibres (Lockwood, Wack, & Burkard, 2001). It is widely believed that these new connections are responsible for the tinnitus sensation in most people, with identification of the mechanisms behind these synaptic connections providing the target for possible pharmacological solutions.

In addition, placebo effects can have a very strong effect on tinnitus patients with depression, with Mihail, Crowley, and Welden (1988) also suggesting the tricyclic drug trimipramine though some antidepressant medications can caused the tinnitus as a side effect (Mills, 1980; Settle, 1991). However, like the tinnitus caused from large doses of aspirin, most cases of tinnitus attributed to antidepressants are reversible after medication stops (Folmer et al, 1999).

Psychotherapy and counselling can also be effective in treating tinnitus patients with depression (Sweetow, 1986). House (1981) noted that tinnitus can become a scapegoat for conflicts and needs, and that it can become a major concern - if not an obsession - leading to further neurotic behaviour: including social withdrawal; isolation; and difficulties with reality. Patients should thus be encouraged to identify problems that can be separated from the presence of the tinnitus sensation. For example, Folmer et al. (1999) suggest that the blaming of tinnitus for difficulties actually caused by hearing loss (e.g. difficulty in nosy conditions) is unhelpful. Instead, amplification through hearing aids will improve speech perception, and possibly even reduce the tinnitus loudness by comparison. Such identification and treatment of problems mistakenly or disproportionately attributed to tinnitus can result in a reduction of the level of importance assigned to the tinnitus sensation.

## STUDY ONE

### Theoretical Basis

The previous chapters have shown the gradual advancement of tinnitus research up until the most recent development discussed here. As can be seen, the overwhelming bulk of early tinnitus research concentrated on objective attempts to associate tinnitus severity with tinnitus distress (e.g. Fowler, 1945; Reed, 1960; Miekle & Taylor Walsh, 1984). This failed, not least because tinnitus is a far more complex phenomenon than was previously considered. This is due in part to the way the tinnitus sensation is continuously orientated to in the auditory cortices of the brain (Figure 4, page 45). In addition, the processes that determine tinnitus annoyance are often highly subjective (Figure 3, page 19), making the distress of the individual almost impossible to predict from severity measurements alone.

Interestingly, much has been made of how the tinnitus sensation is generated. In many ways, through the work of Jastreboff et al. (1996) and others, central theories of tinnitus generation are now quite advanced (e.g. Figure 5, page 51). Problems remain, but the underlying mechanisms that surround tinnitus are now much better understood. Because of this, rapid steps have been made in the management and treatment of tinnitus. Success is variable, tending to be multi-model (e.g. Dineen et al., 1996; Kröener-Herwig et al., 2000), yet the studies supporting them are often fraught with methodological problems. Yet, with all this work, it remains deeply surprising that so little has focussed on the effects of tinnitus on cognition. Granted, it was recognised early on that chronic tinnitus results in: anxiety; depression; insomnia; concentration difficulties; irritability; social withdrawal and so on (e.g. Rizzardio et al., 1998), but not much has been done to ascertain the effect that the presence of the tinnitus sensation has on cognitive mechanisms. Indeed, Rizzardio et al. have stated that the noise becomes more noticeable when the individual is tired, ill or whether it is later on in the day. Furthermore, self-reported concentration difficulties have been well-documented (Tyler & Baker, 1983; Hallam, Jakes, & Hinchcliffe, 1988) but the extent to which these concentration difficulties relate to actual performance is unclear. Does a demanding cognitive task draw attention away from tinnitus, or is tinnitus a potent distracter against performance? McKenna, Hallam, and Shurlock (1995) used some basic cognitive tests to compare the performance of a tinnitus population to a hearing-impaired group. They found only minor differences - but in addition, they failed to compare performance against a normal-hearing control group. Since there is now ample evidence that central processes play a role in tinnitus generation (Jastreboff & Hazell, 1993), and that this involvement has been verified by use of modern brain-imaging techniques (Lockwood et al., 1998), the first step in this direction was taken by Andersson, Eriksson, Lundh. and Lyttkens (2000). Suggesting that tinnitus had the potential for cognitive interference, the authors showed that tinnitus sufferers performed worse than matched controls on a series of six separate versions of the Stroop paradigm (Stroop, 1935). The tinnitus sufferers were also seen to be significantly more anxious and depressed, though these results did not correlate with performance on the Stroop task. Nevertheless, the work of Flor et al. (1995) has allowed us to identify that the tinnitus sensation results in massive reorganisation of the auditory cortex (e.g. Rajan et al., 1994; Mühlnickel et al., 1998). Further, the main strength of Jastreboff's model is the integration of peripheral and central processes. Specific higher order cognition is taking place and as such, it becomes clear that the presence of tinnitus affects multiple systems in the brain and that increasing stress/demands result in increasing tinnitus awareness/distress which may thus impede performance.

Noting that auditory stimuli changing in pitch can affect cognitive processing as well as irrelevant speech, Andersson, Khakpoor, and Lyttkens (2002) referred to work by Jones, Macken, and Murray (1993) and their Changing State Hypothesis. This theorises that changing auditory stimuli are particularly prone to affect cognitive processes, and as such, might have direct implications for tinnitus sufferers. It is plausible that tinnitus, even if only at a subconscious level, represents not a constant stimulus but instead one that fluctuates and is integrated centrally. Thus, internally generated tinnitus could act in similar fashion to external noise. In an attempt to prove this, Andersson et al. (2002) set out so show negative influence of tinnitus on mental activity, taking both tinnitus sufferers and matching controls and using a demanding cognitive task under differing masking conditions: silence; constant white noise; and finally, irregular white noise. Effects of masking were very limited, with neither group affected. Nevertheless, tinnitus sufferers were less effective, their performance consistently lower. In addition, tinnitus sufferers were also found to be significantly more anxious and depressed than their matched controls. In conclusion, it cannot be ruled out that anxiety and depression - and not white noise - were the cause of this performance decrement but the authors also suggested that their task was simply not demanding enough on working memory. Yet it did throw up some important points:

Firstly, tinnitus affects performance on cognitive tasks. As to why this happens, we should look first to basic filter theory. Early selection models such as Broadbent (1958) suggests the presence of a bottleneck, depicting the cognitive system as a communication channel passing information from the environment, processing it, and then responding. Sensory stores maintain fairly accurate representations of stimuli for a short while but the main component is the filter itself. Only a finite amount of information can pass through this filter. That which does is acted upon, that which does not is eventually lost. Yet, models of selective attention - of which this is only one example - deal primarily with one thing, and ignores others. Nevertheless, the individual is capable of dividing their attention and performing more than one task at any particular time. Kahneman (1973) pointed out that real-world tasks frequently require concurrent operation of many perceptual and cognitive processes, his idea being that mental processes compete for access to a limited pool of attentional resources, also referred to as capacity. As such, any two tasks can interfere with each other as long as the total capacity required to perform both of them exceeds capacity available. Multiple Resource Theory states that interference between tasks occurs when tasks compete for the same resources. When they require different resources, no interference occurs (Wickens, 1984; 1991). In addition, the amount of resources we give to a task is flexible. At times, we are more alert or perhaps more motivated to complete a task. Furthermore, there may be an upper limit to the amount of resources available, and it is this aspect of the theory that is of greatest concern here. By definition, chronic tinnitus is constant. That means that it is consistently present, day or night, and that means that some of the finite attentional capacity available to the tinnitus sufferer is constantly attending to the tinnitus sensation.

Therefore, when faced with a cognitive task, it is suggested that the tinnitus sufferer is unable to easily allocate as much in the way of resources as a non-sufferer and under certain circumstances, this should lead to a performance decrement. Therefore, it is proposed to run a series of cognitive tasks comparing tinnitus sufferers to a control group; matched for both age and gender. The tasks themselves are explained in more detail below. Interestingly, tinnitus is processed centrally, particularly when habituation has not occurred - as is especially the case in help-seeking tinnitus sufferers. As such, tinnitus may not truly be an auditory sensation. If it was, then tinnitus sufferers would not have such a clear performance decrement on the Stroop paradigm. For this reason, auditory tasks were discounted. Furthermore - as is well-documented - tinnitus sufferers often have an accompanying hearing loss. And even if not, some level of redundancy will exist. Any auditory cognitive test resulting in performance decrement will not provide conclusive proof that the tinnitus sensation is the cause and should therefore be avoided. In addition, several of the above studies have shown tinnitus sufferers to be more anxious or more depressed than the relevant control group. Many researchers (House, 1981; Lewis et al., 1994; Meric et al. 1998) have concluded that the psychpathological profile of tinnitus sufferers is different to that of those without the condition. For this reason, it is proposed to measure a number of trait variables (e.g. anxiety, depression, fatigue, mental toughness, etc...) and consider these alongside performance at a selection of cognitive tasks.

## Hypotheses

(1) The Decrement Hypothesis. In support of the work of Andersson et al. (2000) and Andersson et al. (2002), it is predicted that tinnitus sufferers will not perform as well as their matched controls at a series of cognitive tasks.

(2) The Trait Hypothesis. By its nature, chronic tinnitus will cause an increase in anxiety and depression. Furthermore, due to sleep difficulties, the tinnitus sample will be more tired/fatigued. In addition, mental toughness will be measured to see whether consistent exposure to a chronic stressor will decrease the robustness of the individual. In all cases, it is hypothesised that the tinnitus sensation will result in a more negative score, through the presence of dysfunctional processes.

## Method

*Participants*

Forty participants volunteered to take part in the study, with every attempt made to match every tinnitus sufferer to a suitable control in regards to both age and gender. Twenty were male and twenty female, gender equally spread between the control group (n = 20) and the experimental group: tinnitus sufferers (n = 20). Average age was 47.88 years (sd. = 18.6), with the tinnitus group slightly older (50.10; sd = 19.9) than the control group (46.65; sd. = 17.4), but not significantly so [$t$ (38) = -.751; $p$ = 0.457 ns.]. The criteria for inclusion as a tinnitus sufferer was the same as that for Andersson et al. (2000); namely Grade II or Grade III severity as defined by the grading system of Klockhoff and Lindblom (1967). For this study, the majority of the tinnitus group was comprised of members of the Hull Self-Help Tinnitus Support Group (HUSH). This would indicate that the majority of the tinnitus sample had trouble coping with their tinnitus in the recent past, suggesting a greater severity of the condition, and/or a reduced ability to cope. Much of the control group were recruited from the social circles of HUSH members, thus also ensuring a good match on socio-economic and education levels. Due to the fact that both the Vienna Determination Task and the Stroop Task rely on colour recognition, all participants were asked whether they suffered from colour-blindness, or any other sight-related disorders. In addition, all held English as their first language.

*Materials (Questionnaires)*

A number of questionnaires were utilised for the study, and a number of separate experiments were conducted. All questionnaires referred to in Study One can be found in their entirety in Appendix A. Two questionnaires were tinnitus-related and as such, the purpose of their construction has been discussed previously.

*Tinnitus Questionnaires (Tinnitus Group only)*

*Subjective Tinnitus Severity Scale (STSS)*

Sixty-two percent of tinnitus sufferers claim their tinnitus varies during the day (Andersson, Lyttkens & Larsen, 1999). As such, it is important to get a measurement that is as accurate as possible at time of testing. The STSS (Halford & Andersson; 1991a) is a speedy 16-item yes/no questionnaire measuring tinnitus severity in simple, quantifiable form. Though some items require recoding, potential scores range from 0-16. Clinical samples revealed high reliability (Andersson et al., 1999), with an alpha coefficient of 0.90. Significant correlations with independent clinical ratings have also been consistently greater that 0.7, showing good validity. As a reference point, the authors suggested scores of twelve or over to be indicative of severe tinnitus. For reasons of conciseness and dependability, the STSS was chosen above other tinnitus-related questionnaires for inclusion.

*Tinnitus Cognitions Questionnaire (TCQ)*

The Tinnitus Cognitions Questionnaire (TCQ) was developed by Wilson and Henry (1998) with the express purpose of providing an instrument to investigate coping characteristics of tinnitus patients; helping to identify particular features that lead to good or poor habituation to the sensation. The identification of such thoughts and beliefs are important in Cognitive Theory (Beck, 1967; Beck, Rush, Shaw & Emery, 1979) and in the case of tinnitus, it can be argued that psychological problems - e.g. depression - are not caused by the presence of tinnitus, but by the individual's perception of their tinnitus. As such, the TCQ was developed to assess such thought processes, consisting of 26 items rated on a five-point (0-4) Likert scale. For each item, respondents were asked to indicate how often they had been aware of thinking particular thoughts on the occasions when they noticed their tinnitus. Questions were organised so that negative and positive items were separated, with clear instructions that the first 13 items were wholly negative, and that the others referred to positive thoughts. Negative items were scored 0-4 and included such statements as "Why me? Why do I have to suffer this horrible noise?" and "Nobody understands how bad the noise is." The positive ones were scored 4-0 and consisted of such items as "There are things in life worse than tinnitus" and "The noise is a nuisance but I just won't let it bother me". The scoring procedure demanded the addition of the two halves, resulting in a single score ranging from 0-104. A high score represents a greater tendency to engage in negative cognitions in response to tinnitus, and a reduced likelihood of engaging in more positive associations. In other words, a higher score indicates greater dysfunctional thinking regarding tinnitus. In terms of validity, psychometric analysis (Wilson & Henry, 1998) indicated good test-retest reliability ($r = 0.88$) and internal consistency (Cronbach's alpha = 0.91). Factor analysis also indicated that the positive and negative cognition scores were distinct factors in their own right. As such, the TCQ would seem a useful measure reporting cognitive responses to tinnitus, perhaps even going as far as demonstrating which people would make the best candidates for Tinnitus Retraining Therapy (TRT). For these reasons, the TCQ was included in the hope that it could add to the explanation of subjective tinnitus severity and the effects thereof. However, as a cautionary note, the authors themselves state that the TCQ is only measuring what people report to be thinking, not the extent to which these thoughts occur.

*Remaining Questionnaires (All participants)*

*General Tiredness Questionnaire (GTQ)*

The General Tiredness Questionnaire was developed by Earle (2004). The purpose being to develop a research instrument capable of measurement a different type of fatigue than state fatigue (below). Through analysis, six factors of fatigue were unearthed: Physical Fatigue; Mental Fatigue; General Fatigue; Morning Tiredness; Evening Tiredness; and Mental Strategies. It was validated through correlations with HADS anxiety ($r = .41$; $p < 0.05$) and HADS depression ($r = 0.36$; $p < 0.005$), with Mental Fatigue correlating especially well with anxiety and Physical Fatigue with depression. The GTQ also correlates negatively with Mental Toughness ($r = -0.43$; $p < 0.05$). It has 24 items, each a statement requiring agreement/disagreement on a five-point Likert scale. With recoding, a total score will range between 24-120, higher scores denoting greater general tiredness. It can found be found in Appendix A.

*Hospital Anxiety and Depression Scale (HADS)*

The Hospital Anxiety and Depression Scale (HADS) was originally designed for use in outpatient departments (Zigmond & Snaith, 1983), with care taken to separate out the concepts of emotional and somatic illness. This ensures that the scale is not affected by either injury or disease. It is a 14-item scale measuring anxiety and depression at once, participants selecting one of the four statements most closely resembling their individual choice of answer. Both anxiety and depression are thus scored from 0-21. For each scale, scores below eight are considered perfectly normal. A score of 8-10 can be considered borderline whereas higher scores indicate possible dysfunction. The internal consistencies (Cronbach alphas) of the two subscales are good, with scores running at 0.80-0.93 for anxiety, and 0.81-0.90 for depression (Herrmann, 1997). Retest reliability shows a high correlation, ($r < 0.80$) after up to three weeks, gradually reducing over longer time intervals. The mean correlation from 18 separate studies (n = 8160) is $r = 0.63$. This indicates that, unlike typical state instruments, HADS is stable enough to withstand situational influences. Conversely, it should be able to respond to mood changes more effectively than typical trait scales. Several authors (e.g. Chaturvedi, Chandra, Channabasa, Benna, & Pandian, 1994) prefer to use the total HADS score as a better measure of overall distress than two separate scales, though there is sufficient evidence that the individual subscales are clinically meaningful. For example, the HADS anxiety subscale is associated with patients suffering multiple acute symptoms, whereas, the HADS depression subscale is cross-sectionally and longitudinally associated with lack of compliance, chronic disease and long-term disability. Moreover, anxiety and depression substantially correlate in a wide variety of studies so this should not be perceived as a flaw in the instrument itself. After an analysis of 200 published studies worldwide, Hermann (1997) describes HADS as "a reliable and valid instrument for assessing anxiety and depression" (p.32). Bjelland, Dahl, Haug, & Neckelmann (2000) concurred.

*Mental Toughness Questionnaire (MTQ48)*

The Mental Toughness Questionnaire was designed by Clough and Earle (2000) to provide a reliable and rapid assessment of the ability of the individual to withstand pressure in a range of environments. It is a 48-item instrument comprising six subscales: *Challenge* - the extent to which an individual is likely to view a challenge as an opportunity. Those scoring highly on this scale will actively tend to seek out such situations for self-development, whereas low scorers may avoid the same situations for fear of failure. *Commitment* - measuring how long an individual is likely to persist with a goal or task. Individuals differ in the degree to which they remain focused on their goals. Some may be more easily distracted, bored or divert their attention to competing goals, whereas others may be more likely to persist. *Confidence* - individuals high in confidence have the self-belief to successfully complete tasks which may be considered too difficult by individuals with similar abilities, but lower confidence levels. The MTQ48 splits this concept into two variables; *confidence in own abilities* and *interpersonal confidence. Control* - the extent to which the individual feels in control of their life. Some people believe that they can exert considerable influence over their surroundings, that they can make a difference and change things. Others feel that the outcomes of events are outside their personal control and that they are unable to exert any influence over themselves or others. In the MTQ48, control is represented by *control of emotions* and *control of own life*. Overall, the MTQ48 has a Cronbach's Alpha value of 0.89 with all individual scales above the recommended 0.70, showing that the questionnaire is indeed reliable. The Mental Toughness Questionnaire also correlates significantly with five categories of the PREVUE personality scale, showing construct validity (MTQ48 Technical Manual; Clough & Earle, 2000). The full MTQ48 is located in Appendix A.

*State Fatigue Inventory (SFI)*

State fatigue can be defined as a "transitory reaction or process taking place at any given time and level of intensity" (Earle, 2004; page 320). In addition, state fatigue has been the focus of much research and debate over the years (Roten, 1982; Krupp, LaRocca, Muir-Nash, & Steinberg; 1989). After all, distinctions exist between mental and physical tiredness (Smets, Garssen, Bionke, & de Haes, 1995). Further, Hockey and Meijman (1998) argue that fatigue is closely linked to both boredom and negative affect. As such, Earle (2004) produced the State Fatigue Inventory - or SFI - an eighteen item instrument. As it turns out, five factors were eventually identified: mental fatigue; physical fatigue; sleep fatigue; negative affect and boredom. The SFI consists of a number of statements corresponding to a five-point Likert scale which allows the participant to indicate how much they agree or disagree with each statement. A copy of the SFI is located in full in Appendix A. With some items needing to be recoded, this allows for an overall state fatigue score between 18-90. In addition, it was found to correlate well with measures of performance ($r = -0.61$; $p < 0.05$) and a number of demand scales. As such, it was decided to use the State Fatigue Inventory as a useful immediate measure of fatigue.

*Materials (Experiments)*

At the beginning of each task, participants were presented with a laminated instruction sheet detailing the requirements of the task to follow. Copies of these instructions are also in Appendix A.

*Odd Man Out Task (OMO)*

The Odd Man Out Task (OMO) was first used by Flowers and Robertson (1985) in a more simplified form. Previously, the OMO task has been used to measure the failure of mental set in people suffering from Parkinson's disease. In other words, OMO measures ability to remember specific instructions at specific times and not to get confused between them. Here, participants were required to state which one of a set of four letters was different from the rest on the basis of a specific pre-determined rule. Two rules were used, the *rule of letter* and the *rule of size*. For example:

Ttht

Here, the rule of letter would dictate that the letter 'h' (second from right) is the odd one out as the other three are all variants of the letter 't'. On the other hand, the rule of size dictates that the capital letter 'T' (on the far left) is the odd one out as it is a capital and the other three are lower-case letters. Some letters were coloured green and others black as an added distracter. Participants were shown a counterbalanced series of four sheets of paper, each with 24 groups of four letters as above - in Ariel, font size 36. Participants were timed by stopwatch as they completed each individual sheet, drawing a line through the letter they believed to be the odd one out as they went. Number of errors made were also recorded.

*Selective Attention Task*

For the Selective Attention Task, participants were required to make use of a computer. Participants sat 60cms away from a 24" computer monitor onto which stimuli were presented. They were asked to look at a specific letter replacing the on-screen fixation point, either an "S" or an "H" - two letters specifically chosen for their differences, as defined in Gibson's Hierarchy of Letters (1971). If an "S" appeared, they were to press "S" on the computer keyboard. If the letter "H" was presented, they were to press the "H" key. There were four conditions, with letters presented on their own or in the presence of flankers. These flanking letters were either congruent (same as the target), incongruent (opposed) or neutral (not related). Font type was Comic Sans MS, size 72. There were 200 trials, 50 of each type of stimulus - in five randomized blocks of 40 that began with an orientating focus point that appeared briefly on the screen (50milliseconds) to aid initial orientation. Response times (in milliseconds) and number of errors made were noted.

*Stroop Paradigm*

The Stroop paradigm variant used here was also computer-based; with the same basic format as described in the section on the Selective Attention Task. The task contained 150 items in total; 50 each of neutral (a line of X's), congruent and incongruent stimuli. Whichever stimulus appeared after the orientating focus point, the participant had only to recognise the colour of the stimuli, not the stimulus itself. In responding, the participant was required to press the corresponding coloured button on the keyboard; red, blue, green or yellow. Each of these was a normal lettered key on the bottom row that had been covered with the corresponding colour. The stimuli were presented in five randomized blocks of 30 and both reaction times (in milliseconds) and number of errors recorded.

*Vienna Determination Task (VDT)*

The Vienna Determination Device is a multiple-stimulus reaction unit. Box-like in shape, it has a work panel inclined towards the participant to allow ease of viewing. This panel is fitted across the top with two parallel rows of five coloured lamps (white, yellow, red, green and blue). The lower part of the panel consists of five buttons, each corresponding to one of the above colours. Other lamps were available, as well as the production of high pitched and low-pitched signals, but these were not utilised. In effect, when a colour signal lights up (i.e. one of the red lamps), the participant is required to press the corresponding button (i.e. the red one). There was an option to report errors back to the participant by way of an error lamp but this feedback option was discounted for simplicity. To endeavour to assist the subject to work at a constant rhythm, a clicking sound could and was produced with each new stimulus. The VDD recorded the responses of the participants in one of three separate ways: a correct response; as an incorrect response; or a delayed response - that is, a correct response but when the button was pressed within a short time of the light moving on to the next coloured bulb.

Since this was an exploratory study, it was decided to have three distinct stages to the task, each a step up in terms of reaction time required. The first stage required a button-press every five seconds for four minutes. This resulted in 48 trials, where any difficultly would stem only from keeping focused on a very undemanding task. The second stage was slightly more challenging, with the light moving at twice the speed, 2.5 seconds, for two minutes. Again, there were 48 trials. Participants were then asked to double their response time again, with the 48 trials being 1.25 seconds apart, taking a total of one minute to complete. As such, participants were able to become more familiar with the task. Without this learning curve, it may well have been impossible to make a decent attempt at the third and fastest stage.

### *Procedure*

The experiment took roughly an hour, under laboratory conditions. Before it took place, all participants were asked to read the Consent Form (see Appendix A). This explained the basic rights of the participants, and made them aware of the confidential nature of the data to be collected. It also allowed age/gender to be recorded and provided the details required for the experimenter to contact participants at a later date with feedback on their individual performances. To begin with, the tinnitus group received one of their two extra questionnaires, the Subjective Tinnitus Severity Scale (STSS), in order to rate subjective opinions of tinnitus severity. From there, all participants completed the State Fatigue Inventory (STI), giving a pre-experimental rating of state fatigue. The four experiments were next, counterbalanced to ensure no single task could adversely affect the others. The STI was then re-issued to provide a rating of post-experimental fatigue. Finally, all participants completed the trait questionnaires: the Hospital Anxiety Depression Scale (HADS), the General Tiredness Questionnaire (GTQ), and the Mental Toughness Questionnaire (MTQ48). The tinnitus group were also asked to complete the Tinnitus Cognitions Questionnaire (TCQ) before being informed that they had finished. The purpose of the experiment was then fully explained and questions answered. Extra time was spent with the experimental group to gain a better working understanding of the effects of tinnitus on lifestyle. However, this aspect was not structured and was only to provide insight.

## RESULTS (Questionnaires)

*Subjective Tinnitus Severity Scale (STSS)*

All tinnitus sufferers completed the STSS, producing a mean score of 7.90 (sd. 3.24), with scores stretching from 3-12. Overall, this indicates that the majority of the tinnitus group complained of a moderate (subjective) tinnitus. Five participants (25%) classified themselves as suffering from severe tinnitus; i.e. a score of 12.

*Tinnitus Cognitions Questionnaire (TCQ)*

As previously stated, the TCQ was only given to tinnitus sufferers, therefore twenty participants completed it. Split into two sections, the TCQ produces scores ranging from 0-52 for both good and bad cognitive styles. The grand total of the TCQ is out of 104, with higher scores denoting an increased likelihood of engaging in negative cognitions and a decreased likelihood of benefiting from more positive ones.

Table 2

*Comparison of cognitive styles employed by the tinnitus sufferer (n = 20)*

| | Mean | Standard deviations |
|---|---|---|
| Bad Cognitions (0-52) | 21.45 | 10.42 |
| Good Cognitions* (0-52) | 11.25 | 8.74 |
| Grand Total (0-104) | 32.70 | 15.52 |

*Higher scores indicate a lack of positive thoughts (a more dysfunctional process).

This total value is lower than the 47.16 (s.d. = 16.20) found by Wilson and Henry (1998) in their original development of the questionnaire. While this indicates that these tinnitus sufferers engage in negative thought processes, the sample differs from the literature, engaging in more positive processes than would be normally expected. Taken alongside the STSS results, it must be concluded that this tinnitus population is not as adversely affected by the condition as might have been expected.

*Hospital Anxiety and Depression Scale (HADS)*

Table 3

*Scores for the anxiety and depression subsections of HADS (n = 40)*

| | Mean scores | | | Standard deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| **Anxiety** | 5.50 | 7.60 | 6.55 | 2.70 | 4.07 | 3.56 |
| **Depression** | 2.50 | 4.00 | 3.25 | 2.24 | 3.45 | 2.97 |

Note: Scores of 8-10 can be considered borderline. Higher scores indicate possible dysfunction.

The descriptives in Table Three denote that neither group is particularly anxious or depressed, going against both the literature and the hypothesis. Having said that, the tinnitus group is close to the borderline anxiety value suggested by Zigmond & Snaith (1983), with nine of the tinnitus group categorised as at least being 'borderline anxious' as opposed to two of the control group.

A MANOVA investigated possible statistical differences between tinnitus sufferers and their matched controls, with Pillai's Trace chosen above the other multivariate statistics on the basis that it is the most robust of the four, and sample size is small. No effect of group was found with regards to the combined anxiety and depression scores, i.e. the total HADS score [$F$ (2, 37) = 1.996; $p$ = 0.150 ns.; Pillai's Trace = 0.10; partial eta squared = 0.097]. The lack of significant effect means analysis of the individual variables was not pursued. As such, there was no significant difference between tinnitus sufferers and matched controls in terms of anxiety or depression. Furthermore, all scores were within normal levels.

*State Fatigue Inventory (SFI)*

As stated in the methodology section (page 87), the State Fatigue Inventory (SFI) was given to participants before ($t_1$) and after ($t_2$) completion of the four experiments.

Table 4

*Descriptive information for the State Fatigue Inventory (n = 20)*

| Timepoint | Mean scores | | | Standard deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| Before | 29.65 | 38.15 | 33.90 | 9.9 | 14.2 | 12.8 |
| After | 36.15 | 37.55 | 36.85 | 7.1 | 9.5 | 8.3 |

A 2x2 mixed ANOVA was used, with group as the independent measure and time of measurement (before/after) as the repeated measure. There was no overall difference in fatigue over time [$F$ (1, 38) = 3.949, $p$ = 0.054 ns.; partial eta squared = .094], though this result tends towards significance. In addition, there was no significant effect of group [$F$ (1, 38) = 2.787; $p$ = 0.103 ns.; partial eta squared = 0.068]. However, the ANOVA highlighted a significant interaction between the two variables [$F$ (1, 38) = 5.718; $p$ = 0.022; partial eta squared = .130].

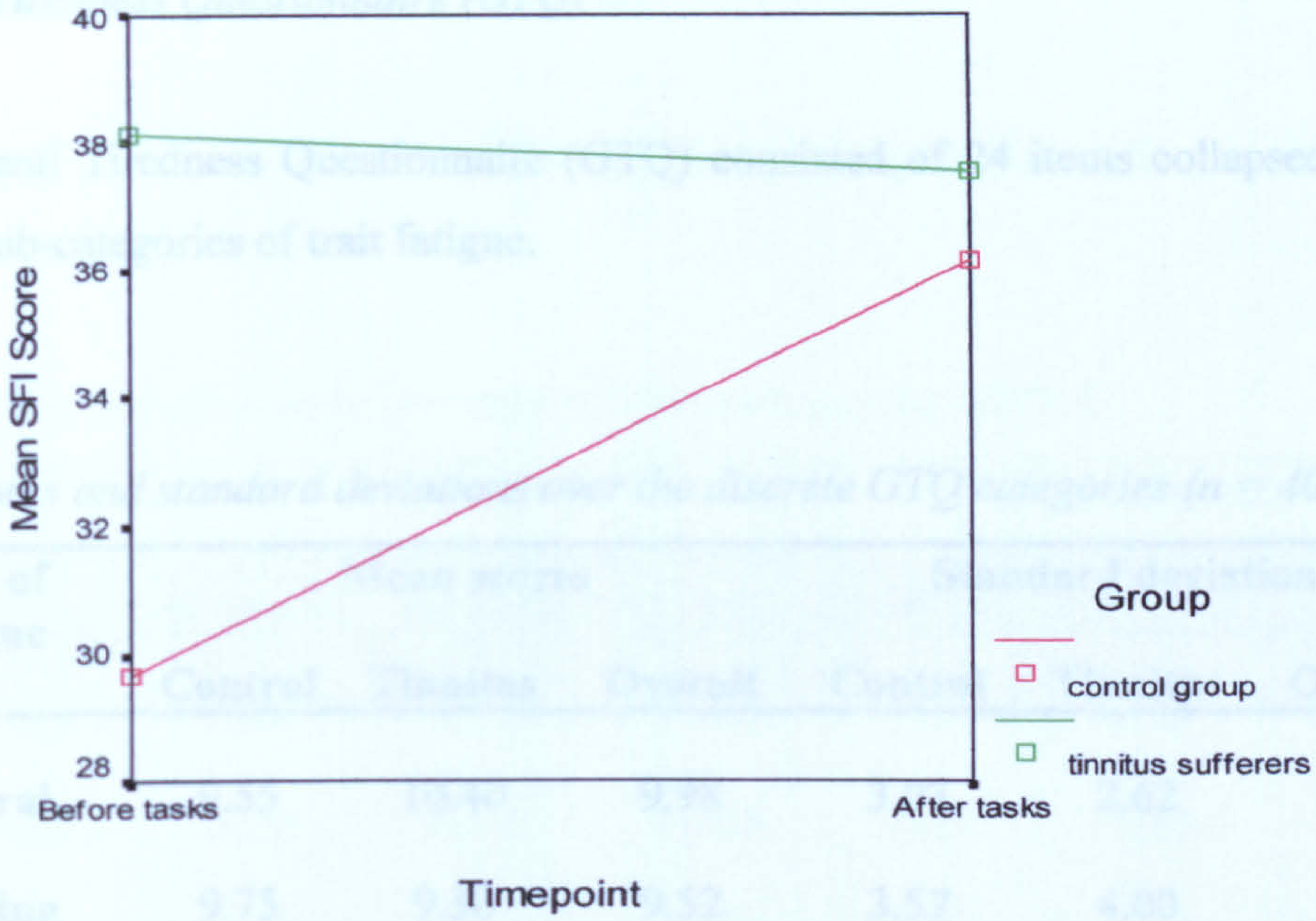



Figure 7: SFI scores for both groups, both before and after the experiment.

While there is no significant difference in state fatigue between tinnitus sufferers and their matched controls, Figure 7 demonstrates that something is happening over time. Immediately prior to the four tasks, the control group was less fatigued, whereas the fatigue scores of the two samples were much more comparable afterwards. Noticeably, there is a sense that the control group tires whereas the tinnitus group was resistant to further tiring. The Trait Hypothesis stated that through known sleep difficulties, tinnitus sufferers would be more anxious, depressed, fatigued, etc., and that this would result in poorer performance. There is partial support here, but only through a greater level of state fatigue before the experiment commenced.

*General Tiredness Questionnaire (GTQ)*

The General Tiredness Questionnaire (GTQ) consisted of 24 items collapsed down into six sub-categories of trait fatigue.

Table 5

*Mean scores and standard deviations over the discrete GTQ categories (n = 40)*

| Type of Fatigue | Mean scores | | | Standard deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| General | 9.55 | 10.40 | 9.98 | 3.03 | 2.62 | 2.83 |
| Morning | 9.75 | 9.30 | 9.52 | 3.57 | 4.00 | 3.75 |
| Evening | 14.35 | 14.70 | 14.53 | 3.79 | 2.70 | 3.25 |
| Physical | 13.85 | 12.90 | 13.37 | 4.57 | 4.27 | 4.39 |
| Mental | 13.20 | 13.25 | 13.23 | 3.14 | 3.26 | 3.16 |
| Strategies | 13.00 | 12.45 | 12.73 | 3.11 | 3.36 | 3.21 |
| Overall | 73.70 | 73.00 | 73.35 | 12.87 | 13.93 | 13.24 |

A MANOVA searched for differences between the two populations. Multivariate tests showed no overall difference in trait fatigue [$F$ (6, 33) = 0.402, $p$ = 0.872 ns.; Pillai's Trace = .068; partial eta squared = .068]. The clear lack of a significant result meant that analyses of the individual variables were not pursued. Therefore, it can be stated that no differences exist between the groups with regards to the General Tiredness Questionnaire.

*Mental Toughness Questionnaire (MTQ48)*

The MTQ48 provides a measurement of six distinct categories as well as overall score.

Table 6

*Descriptives for both populations over all categories of the MTQ48.*

| | Mean scores | | | Standard deviations | | |
|---|---|---|---|---|---|---|
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| **Challenge** | 30.65 | 33.30 | 30.48 | 3.07 | 4.32 | 3.70 |
| **Commitment** | 42.35 | 40.95 | 41.65 | 3.95 | 4.85 | 4.42 |
| **Control (emotion)** | 21.85 | 21.60 | 21.73 | 4.52 | 4.17 | 4.30 |
| **Control (own life)** | 26.05 | 25.45 | 25.75 | 2.84 | 3.84 | 3.65 |
| **Confidence (own abilities)** | 30.35 | 30.10 | 30.22 | 4.614 | 4.62 | 4.56 |
| **Confidence (interpersonal)** | 22.80 | 21.65 | 22.23 | 3.75 | 4.16 | 3.95 |
| **Overall** | 174.05 | 170.05 | 172.05 | 14.34 | 18.43 | 16.42 |

A MANOVA ascertained whether or not tinnitus sufferers were any more or less mentally tough than the control group. As with the GTQ, overall score was not included as a dependent variable. It appeared there was next to no difference between the two populations [$F$ (6, 33) = 0.269, $p$ = 0.948 ns.; Pillai's Trace = 0.047; partial eta squared = 0.047]. As the result was not significant, no further analysis was attempted, allowing the conclusion that no significant difference in mental toughness exists between tinnitus suffers and their matched controls.

Table 7

*Correlation matrix for the questionnaires as completed by all participants (n = 40)*

| Variables | SFI (*t*1) | SFI (*t*2) | HADS (anxiety) | HADS (depress) | GTQ | MTQ48 |
|---|---|---|---|---|---|---|
| **SFI (after)** | .308* | | | | | |
| **HADS (anxiety)** | .581** | .317 | | | | |
| **HADS (depression)** | .395* | .183 | .636** | | | |
| **GTQ** | .221 | .039 | .469** | .513** | | |
| **MTQ48** | -.240 | .004 | -.569** | -.594** | -.595** | |

$p < 0.05$; ** $p < 0.01$.

Table 8

*Correlation matrix for tinnitus suffers only - includes STSS and TCQ (n = 20)*

| Variables | STSS | SFI (*t*1) | SFI (*t*2) | HADS (anxiety) | HADS (depress) | GTQ | MTQ48 |
|---|---|---|---|---|---|---|---|
| **SFI (before)** | .373 | | | | | | |
| **SFI (after)** | .197 | .667** | | | | | |
| **HADS (anxiety)** | .378 | .660** | .461* | | | | |
| **HADS (depression)** | .193 | .247 | .388 | .735** | | | |
| **GTQ** | .021 | .344 | .480* | .667** | .701** | | |
| **MTQ48** | .076 | -.267 | -.319 | -.634** | -.678 | -.500* | |
| **TCQ** | .232 | .241 | .370 | .337 | .251 | .162 | -.297 |

$p < 0.05$; ** $p < 0.01$.

Note compared to Table 7, tinnitus sufferers (Table 8) provide more significant r-values when correlations already exist. Further, performance measures were correlated with HADS anxiety/depression (Appendix A), to ensure it was the presence of tinnitus, not heightened values for these variables, that determined performance.

## RESULTS (Experiments)

*The "Odd Man Out" (OMO) Task*

The Odd Man Out (OMO) task consisted of four separate pages, instructions for and examples of to be found in Appendix A. Two required the participant to conform to the rule of letter and the other two required them to conform to the rule of size. The pages from these tasks were alternated and counterbalanced.

*Rule of Letter*

Table 9

*Completion times and errors made on the rule of letter (n = 40)*

| | Mean times (in seconds) | | | Standard deviations | | |
|---|---|---|---|---|---|---|
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| 1st page | 49.29 | 62.06 | 55.67 | 11.33 | 24.47 | 18.14 |
| 2nd page | 46.80 | 54.45 | 50.62 | 10.81 | 16.87 | 14.51 |
| | **Errors made** | | | **Standard Deviations** | | |
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| 1st page | 22.40 | 21.25 | 21.83 | 5.34 | 6.00 | 5.64 |
| 2nd page | 22.45 | 22.20 | 22.33 | 5.38 | 5.13 | 5.19 |

The rule of letter required 2x2 mixed ANOVAs for both reaction time and errors made. In each case, group was the independent variable and page the repeated measure. For reaction time, there was a significant effect of group [$F$ (1, 38) = 5.399, $p$ = 0.026; partial eta squared = .124], with Table Eight indicating that the tinnitus group responded more slowly than the control group. There was an overall effect of page [$F$ (1, 38) = 4.665; $p$ = 0.037; partial eta squared = 0.109], suggesting a practice effect, namely that after becoming more familiar with the task, participants responded faster on the second attempt. No significant interaction was found [$F$ (1, 38) = 1.200; $p$ = 0.280 ns.; partial eta squared = 0.031].

With errors made, there was no group effect [$F$ (1, 38) = 9.800; $p$ = 0.638 ns.; partial eta squared = 0.006], indicating that the presence of tinnitus as not a factor in performance. There was no effect of page either [$F$ (1, 38) = 0.307; $p$ = 0.582 ns.; partial eta squared = 0.008], so the practise effect was limited to speed, not accuracy. There was no interaction [$F$ (1, 38) = 0.249, $p$ = 0.621 ns.; partial eta squared = 0.008].

Therefore, there results show tinnitus sufferers being just as accurate, but were slower to complete the rule of letter task that their matched controls.

*Rule of Size*

Table 10

*Completion times and errors made for rule of size (n = 40)*

| | **Mean times (in seconds)** | | | **Standard deviations** | | |
|---|---|---|---|---|---|---|
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| 1st page | 51.55 | 53.30 | 52.42 | 16.34 | 24.22 | 20.41 |
| 2nd page | 45.92 | 47.80 | 46.87 | 14.27 | 18.61 | 16.39 |
| | **Mean correct responses (out of 24)** | | | **Standard Deviations** | | |
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| 1st page | 21.30 | 21.45 | 21.38 | 5.81 | 5.03 | 5.37 |
| 2nd page | 22.30 | 21.75 | 22.03 | 5.43 | 5.31 | 5.30 |

Another 2x2 mixed ANOVA investigated the reaction times for the rule of size, with group the independent variable and page number the repeated measure. There was no effect of group [$F$ (1, 38) = 0.112; $p$ = 0.739 ns.; partial eta squared = 0.003]. There was an effect of page [$F$ (1, 38) = 5.252; $p$ = 0.028; partial eta squared = 0.121], reinforcing the concept of an overall practice effect, though no interaction [$F$ (1, 38) = 0.001; $p$ = 0.980 ns.; partial eta squared = 0.000].

A fourth 2x2 mixed ANOVA looked at error rates in the rule of size. No effect of group was apparent [$F$ (1, 38) = 0.015; $p$ = 0.902 ns.; partial eta squared = 0.000]. Further, no effect of page [$F$ (1, 38) = 1.326, $p$ = 0.257 ns.; partial eta squared = 0.034], nor an interaction [$F$ (1, 38) = 0.385, $p$ = 0.539; partial eta squared = 0.010].

In summary of the OMO, the tinnitus group took longer to complete the rule of letter than their comparative controls. However, the error rate was the same. With regard to the rule of size, there was no performance decrement. In each case, a practise effect was observed, with all participants finishing the task faster on the second and subsequent occasion. The question is why the tinnitus completion times are significantly slower for one (i.e. the rule of letter) and not for the other? This argument is taken up in more detail in the discussion.

*Selective Attention Task*

The selective attention task contained stimuli chosen in accordance with Gibson's Hierarchy of Letters (1969). Participants had reaction times recorded in response to the different stimuli presented on screen. Four of these were evaluated. Firstly, response time as dependent on stimulus faced and task progression (fatigue effects). In addition, error rate was similarly investigated.

*Selective Attention response time (by stimulus)*

Table 11

*Mean reaction times for all stimuli (n = 40)*

| Stimuli | Mean Times (in milliseconds) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| Solo | 471.34 | 521.29 | 496.34 | 46.71 | 88.26 | 73.60 |
| Neutral | 495.76 | 547.68 | 521.72 | 59.13 | 108.13 | 89.50 |
| Congruent | 465.11 | 511.70 | 488.41 | 45.63 | 82.60 | 69.46 |
| Incongruent | 500.71 | 561.95 | 531.33 | 61.17 | 118.49 | 97.59 |

The 2x4 mixed ANOVA used group as the independent measure and stimuli as the repeated measure. An effect of group was found [$F$ (1, 38) = 4.257, $p$ = 0.046; partial eta squared = 0.101], with Table Ten showing that the tinnitus group consistently took longer to respond to the on-screen stimuli. Mauchley's Test of Sphericity was significant, requiring correction to ensure that set assumptions were not violated. As such, it was decided to quote Greenhouse-Geisser Epsilon (as advised by Brace, Kemp & Snelgar, 2000; page 191). No interaction took place [$F$ (3,114) = 0.362; $p$ = 0.648 ns.; partial eta squared = 0.009], though there was a significant overall effect of stimuli [$F$ (3, 114) = 15.238, $p$ = 0.001; partial eta squared = 0.393]. This shows that different stimuli provoked different response times.

*Selective Attention response time (across time)*

Table 12

*Mean reaction times across the randomized blocks (n = 40)*

| Block | Mean Times (in milliseconds) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| First (0-40) | 531.14 | 616.53 | 569.34 | 76.38 | 100.40 | 88.39 |
| Second (41-80) | 467.17 | 532.50 | 499.84 | 40.91 | 82.41 | 61.66 |
| Third (81-120) | 466.99 | 522.75 | 494.87 | 51.96 | 82.30 | 66.63 |
| Fourth (121-160) | 478.25 | 508.69 | 493.47 | 54.87 | 69.02 | 61.94 |
| Fifth (161-200) | 492.62 | 510.39 | 501.50 | 64.42 | 74.42 | 68.92 |

A 2x5 mixed ANOVA compared response times over the course of the experiment, ascertaining whether any significant differences emerged due to differing fatigue rates. Group remained the independent measure, and time as the repeated measure. There was no effect of group [$F$ (1, 38) = 3.867; $p$ = 0.057 ns.; partial eta squared = 0.092], though this result tended towards significance. Again, Mauchly's Test of Sphericity was significant, and Greenhouse-Geisser Epsilon values are quoted. There was a significant effect of time [$F$ (4, 152) = 20.732; $p$ = 0.000; partial eta squared = 0.353], suggesting that overall reaction times were altering as the experiment progressed. In addition, there was a sigificant interaction [$F$ (4, 152) = 3.556, $p$ = 0.036; partial eta squared = 0.086]. The nature of this interaction is shown in Figure 8 (page 100).

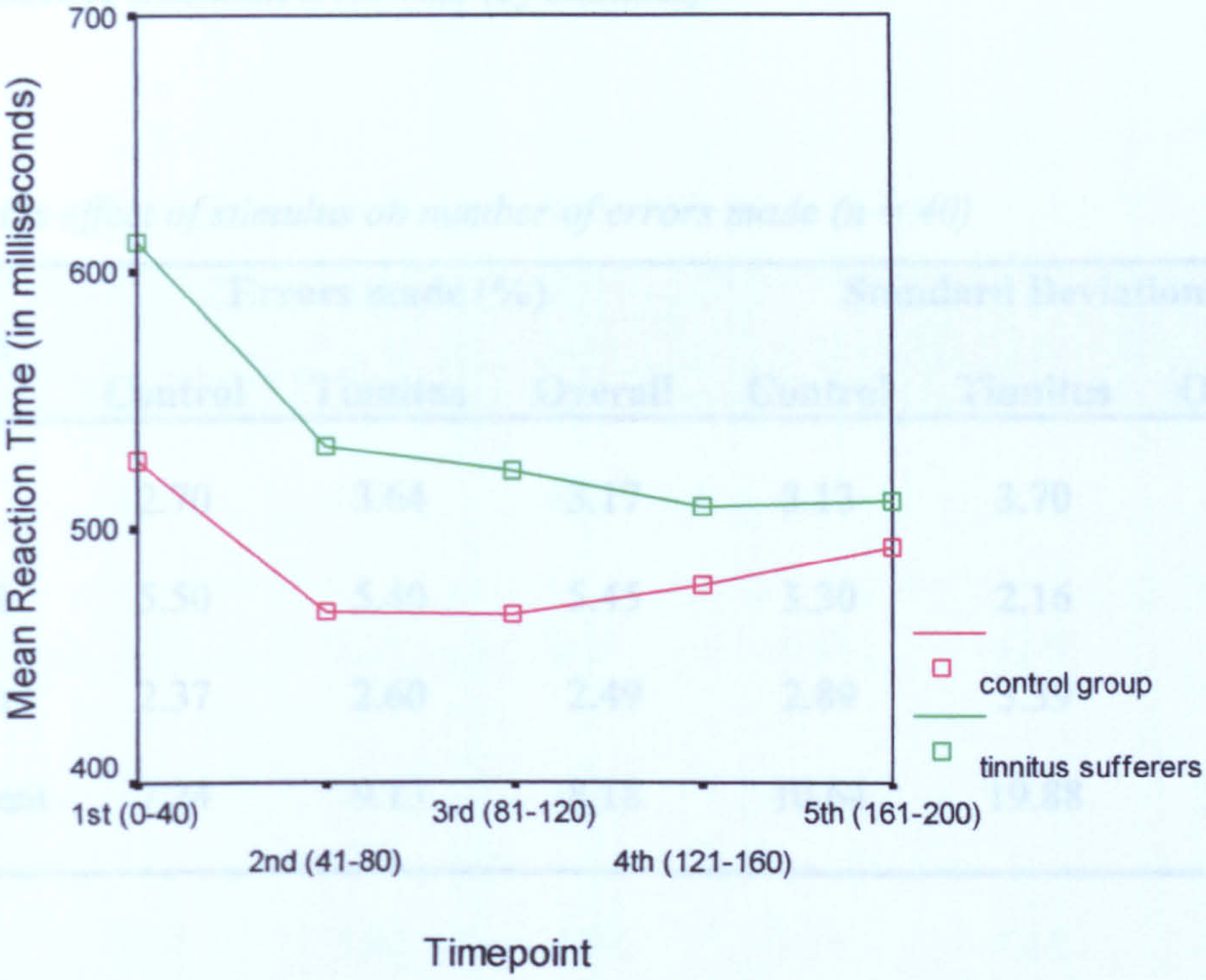



Figure 8: Reaction times by group during the Selective Attention Task.

Figure 8 is important for two reasons. Firstly, it shows a clear practice effect between the first and second randomized block of trials. Secondly, it shows that control group responses slow as time passes, whereas no such effect can be easily discerned for the tinnitus sample. It is likely that this is why there is no significant difference between the two populations, though the results show a tendency for tinnitus sufferers to respond consistently more slowly than their matched controls. Interestingly, these results are similar to those of the SFI (Figure 7, page 91). The control group is seen to tire and above, is also seen to slow. The tinnitus group does not do this, thus resulting in the interaction seen.

*Selective Attention error rate (by stimulus)*

Table 13

*Showing the effect of stimulus on number of errors made (n = 40)*

| Stimuli | Errors made (%) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| Solo | 2.70 | 3.64 | 3.17 | 3.13 | 3.70 | 3.41 |
| Neutral | 5.50 | 5.40 | 5.45 | 3.30 | 2.16 | 2.75 |
| Congruent | 2.37 | 2.60 | 2.49 | 2.89 | 3.39 | 3.11 |
| Incongruent | 7.24 | 9.13 | 8.18 | 10.64 | 19.88 | 15.76 |

A 2x4 mixed ANOVA was utilised to study the effect of stimuli on error rate. Group was the independent measure, and type of stimuli the repeated measure. There was no effect of group [$F$ (1, 38) = 0.280; $p$ = 0.600 ns.; partial eta squared = 0.007], indicating that whatever effect the presence of tinnitus had on performance, it was on reaction time, not accuracy. With Mauchly's Test of Sphericity being significant, Greenhouse-Geisser Epsilon values indicated that there was an overall effect of stimuli [$F$ (3, 114) = 3.865; $p$ = 0.011; partial eta squared = 0.092]. This means that some of the stimuli must be harder than the others. A look at Table Twelve indicates that the incongruent stimuli were responsible for the most errors - though this was the case for both tinnitus sufferers and the matched controls. As such, there was no interaction [$F$ (3, 114) = 0.115, $p$ = 0.765 ns.; partial eta squared = 0.003].

*Selective Attention error rate (across time)*

Table 14

*Mean number of errors across the randomized blocks (n = 40)*

| Block | Errors made (%) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| First (0-40) | 4.63 | 4.75 | 4.69 | 4.81 | 4.79 | 4.74 |
| Second (41-80) | 3.13 | 3.21 | 3.17 | 2.42 | 4.56 | 3.60 |
| Third (81-120) | 3.88 | 5.16 | 4.52 | 4.25 | 7.35 | 5.96 |
| Fourth (121-160) | 3.14 | 5.00 | 4.08 | 3.24 | 4.60 | 4.04 |
| Fifth (161-200) | 4.77 | 4.75 | 4.76 | 5.53 | 7.11 | 6.28 |

Another 2x5 ANOVA investigated possible changes in error rates over time. Group was the independent measure, and randomized block the repeated measure. There was no effect of group [$F$ (1, 38) = 0.252; $p$ = 0.618 ns.; partial eta squared = 0.007], again suggesting that any performance decrement on the part of tinnitus sufferers is not due to reduced accuracy. There was no overall effect of time [$F$ (4, 152) = 1.706; $p$ = 0.152; partial eta squared = 0.043], nor a significant interaction between the two [$F$ (4, 152) = 0.725; $p$ = 0.576 ns.; partial eta squared = 0.019].

In summary, the results of the Selective Attention Task show that tinnitus sufferers perform significantly slower. This slowness allows for accuracy to be maintained.

*The Stroop Paradigm*

The Stroop Paradigm was structured in the same way as the Selective Attention task and so, data was collected in the same way. Similarly, there were five independent blocks of stimuli, carefully counterbalanced. However, for the Stroop Paradigm, three types of stimuli were present: neutral, congruent and incongruent. As in the Selective Attention Task, participants having latency recorded as they responded to the three on-screen stimuli. Again, four separate aspects will be considered. Firstly, response time as dependent on stimulus faced and progression through the task (fatigue effects). Secondly, error rate as affected by the same.

*Stroop Paradigm response time (by stimulus)*

Table 15

*Mean reaction times for all Stroop stimuli (n = 40)*

| Stimuli | Mean Times (in milliseconds) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| Neutral | 831.96 | 1003.23 | 917.60 | 113.74 | 287.02 | 226.71 |
| Congruent | 817.09 | 980.54 | 898.82 | 121.09 | 282.22 | 224.72 |
| Incongruent | 951.11 | 1127.39 | 1039.25 | 187.11 | 332.58 | 277.37 |

A 2x3 mixed ANOVA investigated the effects of the Stroop stimuli on response time. Mauchly's Test of Sphericity was significant, and so Greenhouse-Geisser Epsilon values are quoted. Unsurprisingly with the Stroop paradigm, there was an effect of stimuli [$F$ (2, 76) = 68.133; $p$ = 0.000; partial eta squared = 0.624]. No interaction was found [$F$ (2, 76) = 0.123; $p$ = 0.767 ns.; partial eta squared = 0.003], and in addition, no significant difference between groups [$F$ (1, 38) = 3.983; $p$ = 0.053 ns.; partial eta squared = 0.095]. Yet even though standard deviations are high for the tinnitus sufferers – suggesting the possibility of both low and high performing sub-sets - it must be noted this that this result is firmly tending towards significance and that sample sizes are small, suggesting partial replication of Andersson et al. (2000).

*Stroop Paradigm response time (across time)*

Table 16

*Mean reaction times across the randomized blocks (n = 40)*

| Block | Mean Times (in milliseconds) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| First (0-30) | 1003.71 | 1164.21 | 1083.96 | 182.76 | 294.89 | 252.70 |
| Second (31-60) | 877.74 | 1072.55 | 975.15 | 183.55 | 395.09 | 305.29 |
| Third (61-90) | 833.01 | 980.96 | 906.98 | 154.61 | 299.12 | 243.00 |
| Fourth (91-120) | 842.39 | 988.32 | 915.35 | 143.90 | 290.95 | 234.40 |
| Fifth (121-150) | 815.99 | 970.84 | 893.41 | 130.72 | 274.25 | 221.64 |

The 2x5 mixed ANOVA used experimental group as the independent measure and randomized stimuli block (i.e. time) as the repeated measure. Although results were tending towards significance, there was no main effect of group [$F$ (1, 38) = 3.387; $p$ = 0.074 ns.; partial eta squared = 0.082]. This suggests that while the tinnitus sufferers did respond more slowly, differences were not enough to be significant. Mauchly's Test of Sphericity was again significant, violating some basic assumptions of the ANOVA. As such, Greenhouse-Geisser Epsilon values were used, highlighting a significant main effect of time on performance [$F$ (4, 152) = 32.012; $p$ = 0.000; partial eta squared = 0.457], indicating continuous improvement in response time with increased familiarity. The lack of a meaningful interaction [$F$ (4, 152) = 0.511; $p$ = 0.610 ns.; partial eta squared = 0.094] shows that both populations were affected in similar fashion. Again, as would be expected with the same data, standard deviations for the tinnitus sufferers are much higher. This supports the idea that some tinnitus sufferers are performing much worse than others. For this reason, tinnitus severity may be a factor determining performance, not just the presence of tinnitus.

*Stroop Paradigm error rate (by stimulus)*

Table 17

*Average error rates for Stroop stimuli (n = 40)*

| Stimuli | Errors made (%) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| Neutral | 1.50 | 1.61 | 1.56 | 1.82 | 1.90 | 1.84 |
| Congruent | 1.33 | 0.96 | 1.09 | 1.52 | 1.61 | 1.56 |
| Incongruent | 2.17 | 6.61 | 4.48 | 2.46 | 7.80 | 6.14 |

A 2x3 mixed ANOVA saw another significant result for Mauchley's Test of Sphericity. Greenhouse-Geisser Epsilon values indicated a significant effect of stimulus [$F$ (2, 76) = 10.440; $p$ = 0.00; partial eta squared = 0.216], meaning that type of stimuli plays a considerable part in determining number of errors made. In addition, a significant interaction was found [$F$ (2, 76) = 5.614; $p$ = 0.016; partial eta squared = 0.129]. Finally, no difference was seen between tinnitus sufferers and matched controls regarding errors made on the Stroop paradigm [$F$ (1, 38) = 4.025; $p$ = 0.052 ns.; partial eta squared = 0.096]. However, the results tend strongly towards significance.

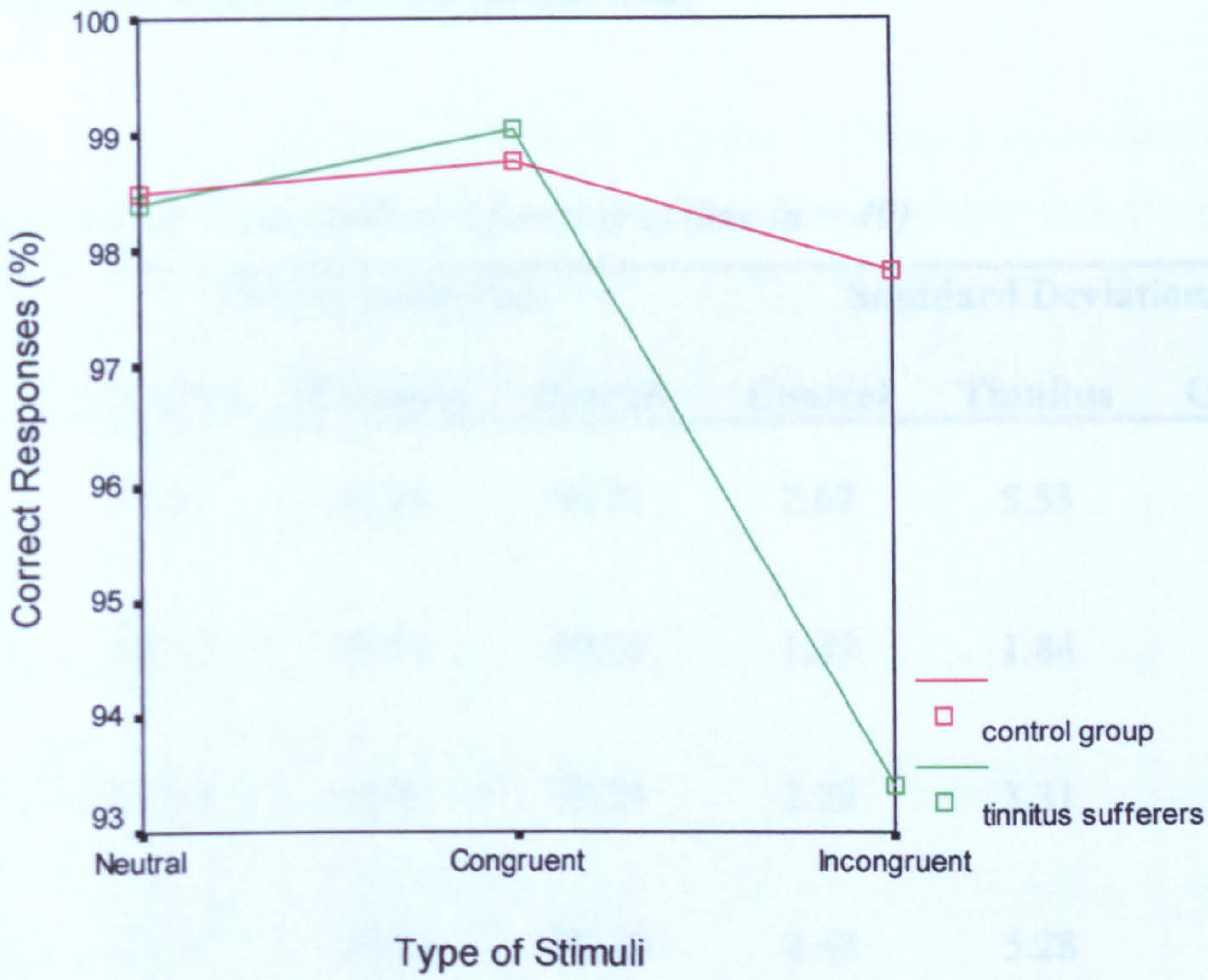



Figure 9: Number of correct responses as determined by Stroop stimuli.

Figure 9 - showing correct responses, not errors made - is indicative of the effect the presence of tinnitus has on accuracy, a clear exaggeration of the classic Stroop effect. With incongruent stimuli, tinnitus sufferers make even more mistakes than a comparable control group - as well as taking more time to process these responses.

*Stroop Paradigm error rate (across time)*

Table 18

*Errors made on the Stroop task as a function of time (n = 40)*

| Block | Errors made (%) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| First (0-30) | 96.67 | 95.33 | 96.71 | 2.67 | 5.53 | 4.40 |
| Second (31-60) | 99.33 | 99.17 | 99.25 | 1.37 | 1.84 | 1.60 |
| Third (61-90) | 98.50 | 98.00 | 98.25 | 2.29 | 3.31 | 2.82 |
| Fourth (91-120) | 97.83 | 96.48 | 97.15 | 2.48 | 5.28 | 4.13 |
| Fifth (121-150) | 97.50 | 96.66 | 97.08 | 3.22 | 4.32 | 3.78 |

A 2x5 mixed ANOVA was the most suitable method to analyse this data. Group was the independent measure, and time the five-level repeated measure. While there was no main effect of group [$F$ (1, 38) = 1.659; $p$ = 0.206 ns.; partial eta squared = 0.042], a significant effect of time was discovered [$F$ (4, 152) = 5.162, $p$ = 0.001; partial eta squared = 0.120], signifying that the error rate altered over time. Table Seventeen suggests this is due to a near-immediate practice effect, followed by a gradual reduction in performance. There was no interaction [$F$ (4,152) = 0.565, $p$ = 0.688 ns.; partial eta squared = 0.015], indicating both samples were affected in similar fashion.

*Vienna Determination Task*

As stated earlier (page 86), there were three stages to the Vienna Determination Task (VDT). All had 48 trials, each demanding a faster response time than the previous stage.

*Stage One*

Table 19
*Performance on the VDT, new stimuli presented every five seconds (n = 40)*

| | Responses (out of 48) | | | Standard deviations | | |
|---|---|---|---|---|---|---|
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| Correct | 47.10 | 46.95 | 47.03 | 1.25 | 1.37 | 1.29 |
| Delayed | 0.05 | 0.15 | 0.10 | 0.22 | 0.37 | 0.30 |
| Wrong | 0.65 | 0.75 | 0.70 | 1.26 | 1.45 | 1.32 |

*Stage Two*

Table 20
*Second stage of the VDT, new stimuli presented every 2.5 seconds (n = 40)*

| | Responses (out of 48) | | | Standard deviations | | |
|---|---|---|---|---|---|---|
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| Correct | 45.75 | 44.90 | 45.32 | 1.37 | 4.60 | 3.38 |
| Delayed | 0.20 | 0.60 | 0.40 | 0.52 | 1.43 | 1.08 |
| Wrong | 0.80 | 0.65 | 0.73 | 1.24 | 1.66 | 1.45 |

*Stage Three*

Table 21

*The final stage of the VDT, with new stimuli every 1.25 seconds (n = 40)*

| | Responses (out of 48) | | | Standard deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| Correct | 26.00 | 16.45 | 21.23 | 8.64 | 11.92 | 11.36 |
| Delayed | 8.15 | 14.20 | 11.18 | 7.84 | 8.20 | 8.50 |
| Wrong | 1.90 | 3.45 | 2.68 | 1.71 | 3.25 | 2.68 |

A 2x3x3 mixed ANOVA investigated the VDT. As ever, group (tinnitus/control) was the independent measure. Stage was a repeated measure - as was the category of response (correct/delayed/incorrect). There was no effect of group [$F$ (1, 38) = 1.233; $p$ = 0.274 ns.; partial eta squared = 0.031], meaning that the tinnitus and control samples performed comparably. Mauchly's Test of Sphericity was found to be significant for all repeated measures, so these results quote Greenhouse-Geisser Epsilon values. There was a significant overall effect of stage [$F$ (2, 152) = 169.067; p = 0.000; partial eta squared = 0.816], indicating that the different response speeds impacted on performance. In addition, there was an overall interaction between the three variables [$F$ (4, 152) = 6.924; $p$ = 0.008; partial eta squared = 0.154]. The interaction between group, stage and response can be best illustrated by the results of Stage Three. As can be seen in Table 21, this is where the interaction must lie. Independent t-tests - with group membership as the grouping variable - saw significant differences between the tinnitus sufferers and their matched controls for both number of correct responses [$t$(38) = 2.901; $p$ = 0.06] and number of delayed responses [$t$(38) = -2.385; $p$ = 0.022]. There was no significant difference for number of wrong responses made [$t$(38) = -1.886; $p$ = 0.067 ns.]. Overall, the two groups performed in similar fashion at the slower speeds, almost inseparable until the third stage - clearly the most challenging. Here, the tinnitus sample were making fewer correct responses, were more likely to respond too slowly, and were close to making significantly more genuine errors than the control group. Therefore the Decrement Hypothesis is accepted when demand increases beyond a certain level.

## Discussion

Several points are immediately apparent from the results section. Taken best in order, let us first consider the results from the Subjective Tinnitus Severity Scale (STSS) and the Tinnitus Cognitions Questionnaire (TCQ). It is clear from the STSS that the tinnitus sample reports a lower level of tinnitus severity than is common to the literature. Many of these papers had access to actual tinnitus clinics and as such, were more likely to collect a biased sample skewed towards high levels of severity. Here, the tinnitus population is not reporting as severe a tinnitus sensation and indeed, the group average suggests a more moderate level of tinnitus than that reported in other studies to date (e.g. Halford & Anderson, 1991; Henry & Wilson, 1996). Five of the total sample (25%) report a severe tinnitus but the rest do not. This means any effect of tinnitus may well be muted, and this may go some way to explain why the overall situation is less clear than what would be expected. Perhaps the lack of clarity is such that that a $p < 0.05$ level of significance is inappropriate, and that an alpha value of $p < 0.10$ may be justifiable (Pedhazur, 1982). As will be stated elsewhere, the small sample size was due to the fact that the study required a clinical population, with time pressure a more potent consideration than the desire for a larger sample - i.e. many people have tinnitus, but a much smaller proportion of the population have chronic tinnitus causing the required distress and their age range ensures limited university access. However, this discussion will continue to use $p < 0.05$ as it remains a suitable significance level and for now, the evidence is not enough to justify such a seismic change. However, it is noted that a number of the ANOVAs reported above tended towards significance in the expected directions and are suggestive of underlying trends discussed in more detail below. The Tinnitus Cognitions Questionnaire (TCQ) also shows the tinnitus group does not appear to be as troubled as past samples (e.g. Wilson & Henry, 1998), with the total dysfunctional score well below that found by the questionnaire originators. Negative cognitions about tinnitus are clearly present, but there is no failure to engage in more positive thought processes. It would seem that the tinnitus group is - on the whole - coping well with the stressor. Looking back at the purported model of Kröner-Herwig et al. (2000) on page 45 (Figure 4), less dysfunctional coping leads to a more balanced appraisal which in turn ensures less attentional resources focusing on the tinnitus sensation. Reduced dysfunctional appraisal should lead indirectly to reduction in the power of tinnitus as a distracter.

This trend is also repeated in the results of the Hospital Anxiety Depression Scale (HADS). While the tinnitus group reports higher anxiety/depression scores, there is no significant difference between the populations and this again goes against what was expected (e.g. Dobie & Sullivan, 1998; Folmer et al., 1999). The performances on the STSS, TCQ and HADS are probably linked, at least in that negative dysfunctional thinking correlates significantly with both STSS scores and Anxiety ratings (page 94). Every effort was made to employ participants who complained about their tinnitus; indeed, the majority were regular members of the local self-help group (HUSH). It was concluded from this that the majority were complaining about their tinnitus, or at least saw it as a negative influence on their lives. Indeed, Hallberg and Erlandsson (1993) stated that help-seeking tinnitus sufferers are much more anxious than non-help seekers. However, this tinnitus population does not appear to have been suffering from the level of severity found in the studies mentioned. In addition, they were more likely to be positive as well as just being negative about their condition. As such, it is commonsensical that they are less anxious and depressed than expected. This too may have contributed to the lack of distinction between controls and tinnitus sufferers in certain aspects of the study at hand.

The Mental Toughness Questionnaire (MTQ48) showed no difference between the two populations - either overall or in any of the sub-categories. This allows the tinnitus group and their matched controls to be placed on par with each other, meaning that the tinnitus group is not more vulnerable nor any weaker mentally merely because of the presence of tinnitus. Since no academic papers have used the MTQ48 in order to measure the robustness of tinnitus sufferers, it is impossible to say whether this holds true in the population at large. However, it is possible to state that moderate tinnitus distress does not appear to have an adverse effect on the mental toughness of the individual. Whether this remains so in the face of more severe tinnitus is impossible to say with this limited sample.

The General Tiredness Questionnaire (GTQ) also failed to pinpoint any differences. This was also unexpected, especially since the literature agrees that one of the major consequences of tinnitus is sleep disturbance (e.g. Davis & Rafaie, 2000), and it is logical to assume that more disturbed sleeping patterns lead to a greater sense of tiredness the following day. Yet the GTQ is a measure of trait fatigue and from these results, the tinnitus group was not affected by a constant tiredness. Interestingly, this means that all trait questionnaires - namely HADS, MTQ48 and the GTQ - failed to identify any differences between the two populations. Therefore, the presence of tinnitus does not bring about changes in the basic nature of the individual (e.g. greater anxiety, more sleep disturbance), at least on the trait variables measured here, with the proviso that this may not hold true for more severe tinnitus than that reported by the sample population.

Interestingly, even without differences in trait fatigue, there were important findings in the investigation of state fatigue - as measured by the State Fatigue Inventory (SFI). These results show a distinct and fascinating effect. Figure 7 (page 91) nicely illustrates that the control group began fresher and became more tired as time went on, as would be expected. Conversely, the tinnitus group was more fatigued to between with, but did not tire further. It would seem that they were immune to the fatiguing effects of taking part in all four experiments (fatiguing effects are assumed due to the increasing state fatigue score of the control group). However, this conclusion should be tempered by the possibility that the tinnitus group may simply not be reporting increasing fatigue. Still, why does the tinnitus group start off more fatigued - especially since the GTQ points out that they are not suffering from higher trait fatigue? There are two possible reasons for this. The first is that while the GTQ has several sub-scales- it is not measuring the most appropriate form of fatigue - that which affects the tinnitus sufferer, e.g. it does not measure sleep disturbance, or perception of sleep disturbance - and that this group is actually more tired than their counterparts. Second is that the tinnitus group was given the STSS to complete prior to testing. This may have resulted in an increased awareness of their tinnitus temporarily increasing its power as a distracter. This in turn could have raised state fatigue as the individual unconsciously attempted to compensate. The fact that the tinnitus group is not tiring further on facing a battery of attentional tasks could be due to the fact that having tinnitus and attempting to ignore it is itself an attentional task - one that takes place twenty-four hours a day, seven days a week. As such, increasing pressure on the individual has only limited effect, at least at lower levels of demand.

Tables 7 and 8 (page 94) are an illustration of the relationship between the questionnaires responses. Central to these interactions is anxiety. A higher level of anxiety is related to: increasing state fatigue; higher levels of depression; and reduced mental toughness. In regards to tinnitus, it would also seem to lead to increased dysfunctional thinking and increasing self-perception of the tinnitus sensation. In addition, a significant relationship exists between positive cognitions and a sense of commitment - the willingness to continue to engage under pressure - which is one of the six sub-categories of which mental toughness is comprised. These findings suggest that a two-pronged approach may be successful in the long-term treatment of tinnitus. Firstly, that reduction in anxiety is crucial as that would have a knock-on effect on a number of important factors. And second, that if the individual is prepared to accept that tinnitus is a long-term condition and that it will have to be dealt with daily on that basis, then a commitment to such a mind set may lead to more positive thoughts and an indirect reduction in the distress that tinnitus causes. Note: there was a possibility that slightly increased depression/anxiety contributed to the performance differences described below so it was decided to correlate HADS subscales with relevant performance measures (Appendix A). These were not significant.

While no trait differences exist between this tinnitus sample and their controls, the results show that tinnitus sufferers did perform worse on a number of tasks. Overall, there is a suggestion in the literature (e.g. Erlandsson et al., 1992; Attias et al., 1995) that tinnitus sufferers are generally worse at cognitive tasks demanding attentional resources. It must be noted from these results that this performance decrement is mainly due to an increased response time, and not due to a reduction in accuracy. As such, maintenance of the tinnitus sensation may well be due to the employment of some of the finite attentional resources available to the individual, making a cognitive bottleneck more likely in certain circumstance and under certain conditions.

The Odd Man Out (OMO) Task has two distinct parts: the rule of letter and the rule of size. Taking the rule of letter first, significant differences existed; namely that tinnitus sufferers took longer to complete the task but still ended up with a comparable number of correct responses. The rule of size was a different matter, with both populations performing in similar fashion. In both sections of OMO, a practice effect was clear - proving the task was unfamiliar to the participants. What needs to be determined is the differences that exist between the rule of letter and the rule of size, and why the presence of tinnitus results in a performance decrement in one but not the other. A referral to the example of a typical OMO stimulus (page 84) is advantageous. As has already been explained, the chosen rule determines which letter is the "odd man out". Setting aside colour as a less relevant distracter, conforming to the rule of size results in the participant scanning the block of letters to identify which letters are upper-case, and which are lower-case. In the most part, this means the individual is distinguishing between symbols that take up more space and those that take up less. In other words, it may be possible to conform to the rule of size without actually having to identify the letters themselves. Therefore, the rule of size could involve less cognitive effort and should be easier to accomplish, whether you have tinnitus or not. On the other hand, the rule of letter requires letter identification and may well require attentional resources more easily available to the control group than the tinnitus group - as on some level, whether consciously or subconsciously, they are also attending to the tinnitus sensation. Since Jastreboff's model (1996) makes clear that tinnitus is processed centrally, it is logical to conclude that tinnitus will interfere more with the higher level task. This is supported by the fact that overall completion times are slightly slower for the rule of letter than for the rule of size

The SAT results suggest something similar, with the tinnitus sample again taking significantly longer. There was no interaction, but there was an overall effect of stimuli, leading to the conclusion that the stimuli varied in difficulty. The difference between tinnitus sufferer and matched control is significant ($p = 0.046$; page 98), and shows there are grounds to suggest this varies between stimuli, being significant for some but not for others. This could depend on task difficulty, with the performance decrement of tinnitus sufferers increasing as the task becomes more challenging. The fact that reaction times change during the course of the experiment is most interesting, especially since the significant interaction (Figure 8, page 101) shows the progression of time affecting each group differently. The control group begins to flag, responding more slowly towards the end of the experiment. The tinnitus group does not, again suggesting some resistance to further fatigue, or that steadily increasing demand results in more attentional resources being gradually re-allocated to the task rather than the tinnitus sensation - reducing its power as a distracter. In terms of error rate, the tinnitus sufferers are just as accurate as the control group (as with OMO).

Logically, both populations found the incongruent stimuli more difficult - both made more mistakes - but no significant difference between groups is apparent. Overall, the tinnitus sample responded slower than but as accurately as the control group. Unfortunately, results of the Stroop paradigm are less clear, with no distinct difference shown between tinnitus sufferers and their matched controls. The *p*-values returned were often slightly more than 0.05 ($p = 0.076$ ns.; $p = 0.053$ ns.), suggesting a relationship without illustrating one Part of this could be due to the moderate level of tinnitus inherent in the sample. In addition, practical factors have meant that sample sizes are small and that standard deviations are higher for the tinnitus group, suggesting greater variance in the experimental group, with some performing akin to the controls and others being more distinct. However, it is still possible to draw valuable insights from the data. Firstly - as expected - the Stroop effect (Stroop, 1935) was clearly replicated and there was an almost significant difference between the groups. There was an effect of time, showing that both groups equally benefited from improved response times once familiarity increased. However, what sets the Stroop paradigm apart from the OMO and the SAT is that there is a strong suggestion of tinnitus sufferers are making considerably more errors on incongruent stimuli (Figure 9, page 106). Another possible explanation of why this result is not quite significant is the fact that, while harder, such stimuli may not be quite hard enough to see a real performance decrement in *moderate* tinnitus sufferers. It is known that tinnitus sufferers made mistakes when dealing with the classic Stroop paradigm, even though response times were not quite shown to be significantly slower here. Thanks to the work of Andersson et al. (2000), it is known that tinnitus sufferers need more time to name coloured words in all conditions and of the three stimuli used, the incongruent ones are obviously the hardest - indeed, they are the basis of the whole Stroop phenomenon. We also know that performance is determined by the speed/accuracy trade-off. For the tinnitus group, it seems that the findings of Andersson et al. are all but replicated in terms of general performance, namely that the Stroop task is more challenging if the individual has chronic tinnitus. Increased demand may show up in different ways depending on the difficulty of what needs to be done. An easier task of attentional interference results in slower response time and a harder one results in higher error rates - greater misjudgement rather than extra thought. This insinuates that the effects of tinnitus must not be viewed in isolation. Indeed, the distracting effect tinnitus appears to hold would seem to vary depending on difficulty of the task.

The Vienna Determination Task is such an example. Each of the three stages required a response in half the time of the one before and at 5.0 seconds and 2.5 seconds per response, there was no difference between the control and the tinnitus populations. It is at Stage Three, with the coloured lights shifting at a more rapid 1.25 seconds, where significant differences become apparent. The device distinguished between correct responses and delayed responses - those that were technically correct but just a little too slow. Since both groups were matched as closely as possible for age as well as for other factors, it is most unlikely that the tinnitus sufferers have slower reactions than the control group, or are more likely to suffer from any other age-related condition. Instead, it is clear that the tinnitus group was suffering interference once demand reached a certain level and that this is due - at least in part - to their tinnitus. Further evidence of the effect size as can be seen in the partial eta squared values (page 109). Yet again, when faced with a cognitive task of attention, the tinnitus population performs less well. In this case, with less correct answers within the time limit, more delayed responses, and more mistakes. Conversely, with more time, it would appear that the required resources can be allocated more effectively.

It would have been of interest to carry out a Multiple Regression analysis to see whether group membership (i.e. control group or tinnitus sufferer), anxiety, depression, fatigue or mental toughness could predict cognitive performance. Unfortunately, for reasons stated previously, sample size was too small. In conclusion therefore, it must be reiterated that the tinnitus group did not report a level of tinnitus severity in line with earlier studies. To an extent, this was to be expected as while many of the participants came from a local self-help group, they were not clinical patients in the manner of most volunteers in the literature. It may be that this tinnitus sample was more vulnerable to tinnitus rather than suffering from a more severe form (e.g. Vernon, 1976; Tyler et al., 1992), but the results of HADS and the MTQ48 make this less likely. As such, the effects of tinnitus are probably more limited than they would have been otherwise. Since the tinnitus group was less anxious/depressed, this too could have had an effect. The SFI provokes important questions, with a distinct difference in fatigue between the groups. Table 7 (page 94) shows a significant correlation between pre-experimental fatigue and depression and anxiety, as well as a negative correlation with confidence in own abilities. While no significant differences existed for these variables, this still suggests the presence of complex interactions. It is clear that the tinnitus group began the experiment in a greater state of fatigue. More importantly, tinnitus sufferers may be less vulnerable to increasing fatigue on attentional tasks. As such, a second study is proposed with a similar set-up, with the tasks lengthened and made more difficult, in order to provoke greater fatigue. After all, even if tinnitus sufferers are less vulnerable to fatigue, it would be most surprising to find that they are invulnerable to it. In addition, when fatigue increases, what further effect will this have on task performance in tinnitus sufferers? The OMO task shows a distinction between the rules of letter and size, namely that the rule of letter promotes reduced efficiency from individuals with tinnitus. Therefore it is proposed an adjusted OMO task is used for the aforementioned second study, being of the same length but only using the rule of letter. This has the advantage being able to confirm whether people with tinnitus do indeed struggle on such a task. It is appropriate as the testing of mental set is no longer applicable. The Selective Attention Task saw the presence of tinnitus having an effect on response time, if not on number of errors made. The fact that both populations seemed to undergo different effects under increasing mental fatigue means that a new version of the Selective Attention Task is proposed, with increased length and difficulty (i.e. fewer incongruent stimuli, thus reducing familiarity). Finally, the results of the Stroop task were broadly in line with Andersson et al. (2000). However, results were not quite significant. To properly replicate the study, it would mean repeating the Stroop paradigm in the next study, at a time when the author is seeking to move forward and further investigate the effects of tinnitus. Therefore, it is not proposed that the next study takes advantage of this paradigm. The same can be said of the Vienna Determination task, as the results clearly follow the hypothesis, namely that the performance of the tinnitus group suffered under the most difficult condition. This is very important; yet further stretching this task to increase difficulty and increasing fatigue would probably mean increasing demanded response time to a point beyond that which is practically meaningful. Instead, it is proposed to replace these tasks with others to investigate the effect of tinnitus on sustained attention. So far, the above tasks have demanded a response to each and every stimulus. While this approach is to be continued, the findings of the STI did not go far enough. The next stage is to provoke increasing fatigue and compare group performance. For this, tasks of sustained attention - or vigilance - will be best. These are envisaged as lengthy, requiring a response when specific parameters are reached.

## PILOT STUDY - STUDY TWO

### Theoretical Basis

Study One provided a number of interesting results, but also indicated that a different approach would be needed in order to accurately explain the effect the presence of tinnitus has on cognitive performance. First of all, the next laboratory study will be longer than the previous one - to facilitate an increase in state fatigue. This could be achieved in two ways; either by increasing the battery of tests available, or by increasing the length of the ones already present. Of the four tasks undertaken, the Vienna Determination Device has already shown a clear difference in performance between the experimental tinnitus group and their matched controls and there is little to gain from utilising it again. The Stroop task - as previously stated - was broadly in line with the results of Andersson et al. (2000), though it could have benefited tremendously from the previously suggested and discounted change in alpha values to make $p < 0.1$ a significant result (Pedhazur, 1982). However, it was felt that repeating and replicating the Stroop paradigm to support Andersson et al. would not be the step forward required of a second study. It is therefore enough to note the results of the Stroop paradigm and move on. The Odd Man Out (OMO) task did show an effect of tinnitus on certain types of mental activity. As such, it was decided to retain it. However, since one of the objectives of Study Two will be to see what happens to state fatigue when participants are pushed further than in Study One, it seems logical to keep to four pages but simply use the rule of letter throughout. This should - in theory - promote a clearer distinction between tinnitus sufferer and matched control. Increasing actual length of the task was considered but rejected due to difficulties comparing the two versions. In addition, a particularly steep practice effect was observed in the case of the tinnitus population (Figure 7, page 91). And if implemented, more pages would reduce overall differences between the OMO and the new version (i.e. same length). Finally, the Selective Attention task requires inclusion if only on the grounds of not being very clear-cut in Study One. These results (page 100) indicated a similar effect to the State Fatigue Inventory (SFI); namely the control group suffering a performance decrement (latency) over time which was not replicated by the tinnitus sample (slower overall). This interaction shows a longer Selective Attention task to be of advantage. In addition, it is proposed to increase difficulty further by reducing the number of incongruent stimuli present (MacLeod, 1991). Fewer incongruent stimuli result in each one being more potent, allowing for greater difference in responses to the stimuli, increasing hopes of significant interaction.

Yet this leaves only two experiments; both a little harder, with one significantly longer than previously. Other tests are required and as such it was determined to increase the range of attentional tasks available. Study One used tests of attention, but with tinnitus being a chronic condition, it may be more appropriate to use tasks of *sustained* attention in order to better ascertain just what effects the presence of tinnitus incurs. Indeed, constant surveillance of stimuli may more effectively mimic the demands of the tinnitus sensation, even if action is only irregularly demanded. A perfect example of a task of sustained attention is the Mackworth Clock Task (Mackworth, 1948) and used since in a number of different formats (e.g. Giambra & Quilter, 1988). The original was a mechanically-driven clock face with the second hand visible and no other markings of any kind. This hand would advance in discrete steps once per second, one hundred such movements completing the circle. Over the first half hour, the hand would advance a double distance on twelve occasions, spaced out at a variety of intervals. The participant had to spot these double-moves and respond by pressing a button. Succeeding half-hours would repeat the same sequence and there were no breaks between half-hour periods. In their version, Giambra and Quilter (1988) investigated the effect of age on sustained attention and used the Mackworth Clock Task (MCT), stating its value as a sensory discrimination task with virtually no memory demand. Using their mechanical version, they found the MCT to be rather insensitive to age. This is also of use as many tinnitus sufferers are of middle-age or beyond. In addition, numerous studies (e.g. Lichstein, Riedal, & Richman, 2000) found no differences between men and women. Furthermore, they found no association between MCT performance and either depression or anxiety. The main problem with the MCT is that it is not commercially available and, while numerous variations have appeared in the literature (e.g. Putz, 1975; Giambra & Quilter, 1988; Monk, Buyss, Reynolds, Jarrett, & Kupfer, 1992), the testing instrument has varied each time. For example, Lichstein et al. state the mean frequency of signal events has varied from one every forty seconds (Putz & Roche, 1974) to once every one hundred and sixty seconds (Giambra & Quilter, 1988). In addition, the length of the experiment itself often varies, ranging from twenty minutes (Putz & Roche, 1974) to over an hour-and-a-half (Putz, 1975). Lichstein et al. also stated that they had found sixteen published instances of the MCT between 1970-2000, with a new device on each occasion. As such, the MCT has not attracted much interest, even though it has highly commendable qualities: i.e. indifference to age and gender; and lack of memory load. It is a "lengthy, monotonous vigilance task that would expose performance decrements arising from sleepiness" (Lichstein et al., 2000; page 154) and is perfect for this study. The more up-to-date computerised version of the MCT reported by Lichstein et al. shows that a mechanical set-up is unnecessary in these times and since they also bemoan the lack of standard practice in the implementation of the MCT, a pilot study is essential. This is due to the fact that the MCT is rather tedious and that participants would look favourably on attempts to keep session length at a minimum. Therefore, one valuable purpose of this pilot is to determine an acceptable length of the MCT that will both provide data (i.e. force errors) and keep participants engaged. For example, the original study (Mackworth, 1948) indicates that psychological resources are more heavily taxed in the second half hour. Clearly, a MCT variant of such a length would be very useful but it will also involve participants being sat there for an hour. Drop out rates would be high and annoyance and irritability caused by the MCT would no doubt affect performance on the other tasks.

Nevertheless, one task of sustained attention is not enough. In Study One, the OMO suggested a performance decrement in tinnitus sufferers on the rule of letter - and this requires letter identification. As such, it is theorised that a task of sustained attention involving letters is appropriate, something involving a number of letters presented on screen with the participant required to respond when a specific letter appears. In order to differentiate it from the Selective Attention experiment, it is proposed to have letters on screen all the time so that the monitoring aspect of the task is constant, then for some method of highlighting these letters to move around the screen in seemingly random fashion. If these letters are also similar, it should initiate the higher processing demands that the tinnitus sensation would seem to interfere with. From this suggestion, a 'Grid' task is proposed whereby a lattice is on screen, each section of the grid filled with a letter "b", "d", "p" or "q" of an appropriate font to ensure all stimuli are the same, differences achieved only by rotation or mirror imagery.

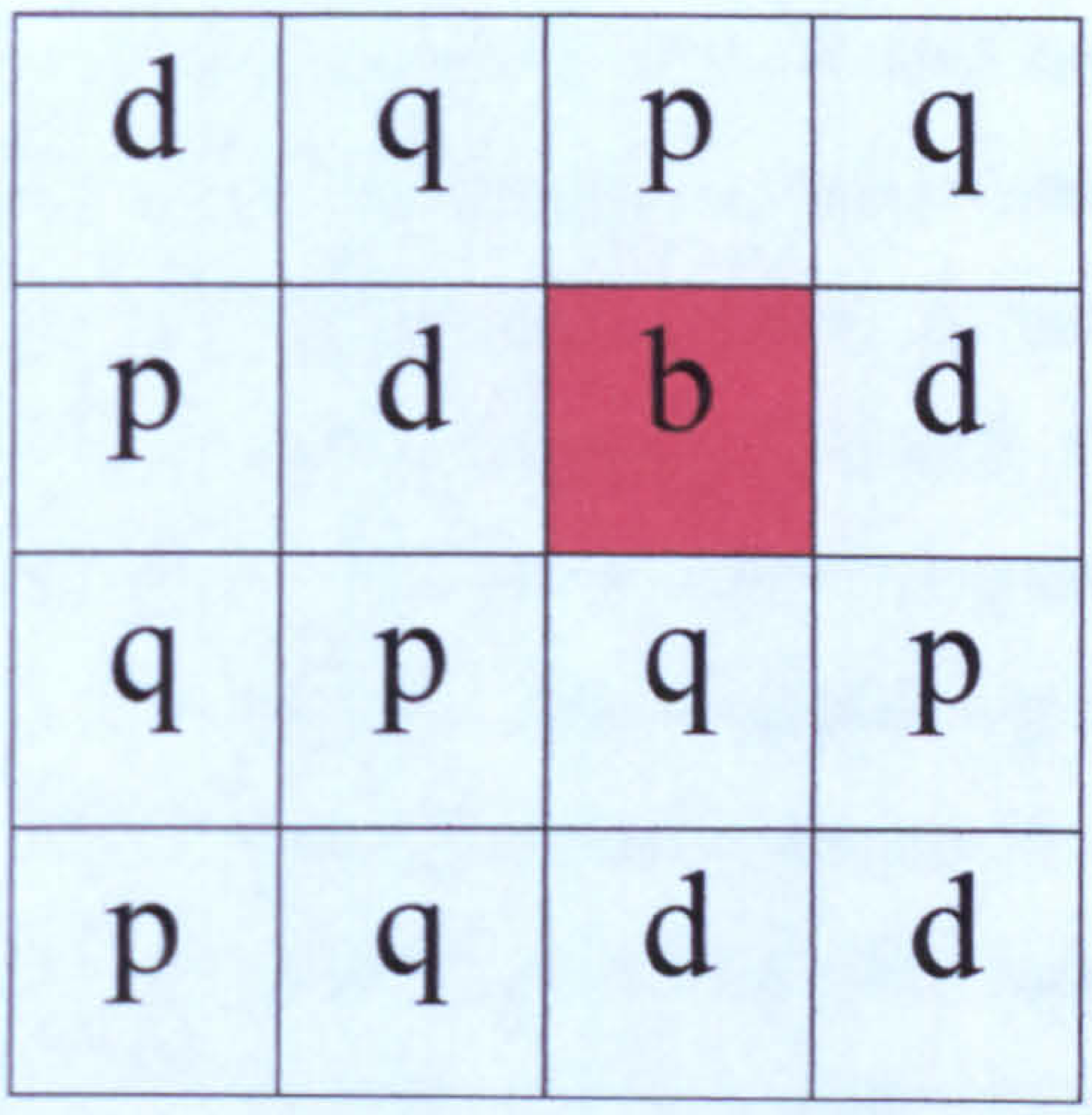



Figure 10: A depiction of the grid task.

Figure 10 shows the basic concept of the experiment. The participant will see the red square move across the grid, responding when one particular letter - in this case "b" - is highlighted, but otherwise merely monitoring activity.

In addition, a number of questionnaires were planned. Obviously, the State Fatigue Inventory (SFI) should be maintained - as should the Subject Tinnitus Severity Scale (STSS) in the actual study. The Tinnitus Cognitions Questionnaire (TCQ), the Mental Toughness Questionnaire (MTQ) and the General Tiredness Questionnaire (GTQ) will be removed as they did not provide a great deal of meaningful data. More controversial is the Hospital Anxiety Depression Scale (HADS) as, while it did not illustrate any differences in the two populations, anxiety and depression have consistently been shown higher in tinnitus sufferers in the past. Yet the first study was also an attempt to achieve the broadest possible line of attack and because of this, Study Two should be pinpointing that which is most useful. As such, there is a case for leaving HADS out as well, in order to streamline the process and avoid the use of too many questionnaires that are overly negative. For these reasons, only the SFI will be utilised here - the STSS will also be used under experimental conditions but not in this control-only pilot.

Beyond this, Study Two should go further. It is all well and good to say that tinnitus sufferers undergo a performance decrement in certain situations but how does that reflect on the experience that the tinnitus sufferer is facing? Do the hypotheses provided at the end of Study One ring true - namely that the tinnitus sensation interferes with processing and if so, is the sufferer more aware of their tinnitus when they are under pressure? It is stated in the literature (e.g. House, 1981; Jakes et al., 1985; Erlandsson et al., 1991) that tinnitus is perceived as being worse when the individual is under strain but no real experimental effort appears to have been made to confirm this. In addition, there is no inference that this is also the case under low stress. What is proposed for Study Two is that participants subjectively rate how difficult they perceive each task to be. More than that, each member of the tinnitus (experimental) group should also rate how aware they are of their tinnitus - compared to how it is normally - after each task. That way, it can be seen which tasks are easier and which tasks are harder. More importantly still, it will be possible to see how the interaction of task difficulty (subjective) and tinnitus awareness (also subjective) affect task performance.

In summary, differences between Study Two and Study One are twofold: firstly, two tasks of sustained attention have been included; and that secondly, each task is more demanding than before. This last point is important as simply increasing the length of a task may affect performance in later tasks, though counterbalancing goes some way to prevent this. Some of the following tasks are quite long, the Mackworth Clock task in particular. Therefore, it is clear that some sort of distracter may be required between tasks - particularly after the MCT - to discount the possibility of this occurring. As such, a buzzwire was obtained in order to provide a distracting spatial challenge between experiments, giving participants a 30 second rest before returning to the attentional tasks at hand. This buzzwire was quite basic with batteries to power the buzzer in case the wire was tapped with the probe and a circuit formed. It was also linked to a red light bulb, in case it was decided to keep the buzzwire for the Study proper, allowing it to retain its usefulness for participants with tinnitus/hearing disorders.

## Method

### *Participants*

Twenty participants volunteered their time to take part in the pilot study, all of whom were undergraduate psychology students at the University of Hull. No volunteer suffered from tinnitus and they were used partly to get a feel of the planned study, and partly to get a better idea of how the tasks worked and interacted. Primary motivation was to ascertain whether or not the selected tasks seemed appropriate (i.e. produced enough unforced errors), and to judge whether the tasks were of varying difficulty levels. In addition, the available experimental sample size was small; and tinnitus sufferers would be needed again to take part in the actual study after becoming familiarized with the tasks. As such, their use here was avoided. Nine participants were male and eleven were female. The average age was 22.60 (s.d. = 4.325) which indicated a younger sample than would be used in the study itself. No participants held sight-related disorders and all held English as a first language.

### *Materials*

Only one questionnaire was used - the State Fatigue Inventory (SFI). It was completed before and after the experiment in order to measure possible fatiguing effects. In the real study, it is also proposed to include the Subjective Tinnitus Severity Scale (STSS) but, as the pilot contains only a sample of controls, this was left out. At all times, laminated instructions were provided to explain what was required of participants. These can be found with the consent form in Appendix B.

*Grid Task*

The Grid task was entirely new and, as such, required piloting to provide some guide of what could be expected from a control sample (the baseline) in Study Two proper. In addition, the pilot study would help show whether the Grid task was appropriate. Three separate sub-sections were utilised, each with slightly different properties to the other two. The first Grid was a simple 4x4 affair taking up a little less than half of the 24" computer screen and consisted of an equal - if randomly placed - number of b's, d's, p's and q's. It was decided arbitrarily that the target letter would be the letter "b", and as the test ran, it would be highlighted 10% of the time as opposed to the 30% equally due the three other letters. When the letter "b" appeared, the participant was instructed to press the spacebar. Otherwise, they were asked to do nothing. This first orientating Grid appeared on-screen for a total of forty seconds and, as such, the target letter was highlighted four times only. The second grid was slightly larger, consisting of a 10x8 matrix that took up roughly three-quarters of the PC screen. Again, the four possible letters were spread equally across the grid. This sub-task ran for a total of two minutes, with the target letter requiring a response on twelve separate occasions. The final Grid was a 20x13 matrix and, though the individual blocks were slightly smaller, the grid took up the entire screen. Each letter was equally represented in this eight minute version (480 highlights in total). However, on this final occasion, the target letter was highlighted only 5% of the time and so appeared on only 24 distinct occasions. The response time to each appearance of the letter "b" was noted, as well as number of errors made by the participants - whether these mistakes were false positives or a simple failure to respond when required.

*Mackworth Clock Task*

The Mackworth Clock task (MCT) was constructed to order, and consisted of twelve circles mimicking a clock face. Once the task began, the circle in the twelve o'clock position was lit for one second, then the circle at one o'clock and so on. As the test progressed, participants were asked to monitor the progress of the highlighted circle and press the spacebar on the keyboard when noticing that it skipped a section. Since it would be difficult to quickly work out what length of MCT was appropriate, it was decided to split the task into three sub-sections again. The first of these was short, only forty seconds long - with four "skips" - and was designed purely to orientate the participant to what was required of them. The second was three minutes in length, and had eight skips. The final subsection was a much longer fifteen minutes and contained sixteen skips, slightly over one a minute. Average response time was recorded alongside number of errors made, whether false positives or simple misses.

*Odd One Out ($O^3$) Task*

As stated above, the Odd Man Out (OMO) task was fine-tuned to further challenge tinnitus sufferers. Although the new task is broadly the same, keeping the same number of pages and the same layout of Study One (see Appendix A) it will only use the rule of letter. As such the previous explanation of the task (page 84) is still relevant, though new laminated instructions were provided (Appendix B). The four sheets continued to be counterbalanced and fonts remained constant. In order to distinguish between the two, the variation utilised here will be referred to as the Odd One Out ($O^3$) task.

*Selective Attention Task*

As before, the Selective Attention task was computer-based, with participants looking at specific letters as they replaced an on-screen fixation point. This letter would be either an "H" or an "S" (Gibson, 1969). If an "S" appeared, participants were instructed to press the "S" key and if an "H" appeared they were told to press the "H" key. Again, there were four conditions with the letters either being presented on their own or in the presence of flankers. These were either congruent (same as target letter); incongruent (opposite to the target letter); or neutral (unrelated). Neutral flankers were either the letter "P" or the letter "Q". Font type was Comic Sans MS, size 72. There were 450 trials, a more than two-fold increase on the previous study. Incongruent stimuli were proportionately reduced - only 75 trials, compared to 125 for the other stimuli. There were five counterbalanced blocks of ninety trials, each beginning with a focus point (50 milliseconds) to aid orientation. Response times (milliseconds) and errors made were recorded.

*Procedure*

As each participant arrived, they were given the consent form and had the broad guidelines of the pilot study explained to them. They were informed that this was a pilot study only and that they should point out any mistakes that they noticed for correction (e.g. typing mistakes, etc.). Once the consent form had been signed, participants were asked to complete the first State Fatigue Inventory (SFI) and then move on to the four counterbalanced tasks, with the participants asked to rate their perception of task difficulty on a scale of one to five (Appendix B) on completion. Between tasks, participants were also asked to attempt the buzzwire task, returning the probe to the beginning and starting again if the buzzer sounded. Once all four tasks were completed and rated, the SFI was filled in again and participants thanked for their time by the researcher.

## Results

*State Fatigue Inventory*

The State Fatigue Inventory (SFI) was used to investigate the effects that the four experimental tasks have in increasing the state fatigue of the participants. As such, scores were recorded before and after the experiment.

Table 22

*Means and standard deviations for SFI (before and after)*

| State Fatigue (before experiments) | State Fatigue (after experiments) |
|---|---|
| 36.20 (s.d. 12.01) | 45.20 (s.d. 12.67) |

The repeated measures ANOVA showed a significant main effect of fatigue [$F$ (1, 19) = 14.571; $p$ = 0.001; partial eta squared = 0.434]. This indicates that the tasks were tiring the sample population.

*Grid Task*

The Grid task was made up of three distinct sub-sections, each slightly different in terms of size and duration. Reaction times and numbers of errors made were noted along with subjective levels of difficulty, as reported by the participants themselves.

Table 23

*Mean difficulty ratings (subjective), latency per individual stimulus, and number of errors made in the Grid task*

| | Perceived difficulty (1- 5) | Reaction Time (milliseconds) | Number of errors |
|---|---|---|---|
| Section One | 1.70 (0.98) | 627.69 (75.48) | 0.35 (0.49) |
| Section Two | 2.20 (0.84) | 723.78 (51.73) | 0.65 (0.93) |
| Section Three | 3.55 (0.89) | 740.04 (42.06) | 2.85 (1.97) |

With sub-section as the independent measure, and with several dependant variables, repeated measure ANOVAs showed a main effect of difficulty [$F$ (2, 38) = 45.295; $p$ = 0.000; partial eta squared = 0.704]. Least significant difference (LSD) post hoc tests indicated distinct differences between sub-sections one and two ($p$ = 0.014); one and three ($p$ = 0.000); and two and three ($p$ = 0.000). This suggests that increasing size and duration of the task is complemented by realisation of increasing difficulty. There was also a main effect of reaction time [$F$ (2, 38) = 30.036; $p$ = 0.000; partial eta squared = 0.613], with LSD tests showing differences between sub-sections one and two ($p$ = 0.000), and one and three ($p$ = 0.000). However, there was no difference between sub-sections two and three ($p$ = 0.294 ns.). This suggests an upper limit to how much size and duration affect response time. There was also a main effect of errors made [$F$ (2, 38) = 24.084, $p$ = 0.00; partial eta squared = 0.559]. Post hocs illustrated significant differences between the first and third ($p$ = 0.000) and second and third subsection ($p$ = 0.000); but not sub-sections one and two ($p$ = 0.186 ns). This is to be expected as a longer task results in more opportunity to make errors.

*Mackworth Clock Task*

The Mackworth Clock task (MCT) was split into three sub-sections. Each came one after the other, with no break between them except to reiterate the parameters of the next, and to ask the perceived difficulty of the sub-section on completion.

Table 24

*Difficulty ratings (subjective), response times per individual stimuli, and errors made*

| | **Perceived difficulty (1- 5)** | **Reaction Time (milliseconds)** | **Number of errors** |
|---|---|---|---|
| Section One | 1.15 (0.37) | 577.45 (65.81) | 0.25 (0.55) |
| Section Two | 1.80 (0.70) | 621.45 (67.90) | 0.20 (0.41) |
| Section Three | 2.95 (1.05) | 715.84 (68.62) | 1.00 (1.62) |

Repeated measure ANOVAs were able to illustrate a significant main effect of difficulty [$F$ (2, 38) = 37.660; $p$ = 0.000; partial eta squared = 0.665] indicating participants perceived a difference in the relative difficulties of the various sub-tasks. Least Significant Difference (LSD) post hoc tests showed this held true for all three sub-tasks: section one being easier than section two ($p$ = 0.001) and three ($p$ = 0.000); and section two also easier than section three ($p$ = 0.000). In addition, there was a significant effect of reaction time [$F$ (2, 38) = 45.108; $p$ = 0.000; partial eta squared = 0.704]. The LSD found significant differences between all three MCT sub-sections; between one and two ($p$ = 0.019); one and three ($p$ = 0.000); and parts two and three ($p$ = 0.000). With regards to errors made, Mauchly's Test for Sphericity was significant, requiring the use of Greenhouse-Geisser instead [$F$ (2, 38) = 4.775; $p$ = 0.014; partial eta squared = 0.201]. Employing the LSD, the difference was found to lie between sections one and three ($p$ = 0.044) and two and three ($p$ = 0.028). There was no significant difference between parts one and two ($p$ = 0.716 ns.). As such, significantly more errors were made in the fifteen minute condition than in the two shorter ones.

*Odd One Out ($O^3$) Task*

With only one aspect of the $O^3$ task, participants were only asked the once as to how challenging (out of five) they found it to be (mean = 2.40; sd = 1.142).

Table 25

*Changing performance throughout the $O^3$ task (rule of letter)*

| | Completion Time (seconds) | Number of errors |
|---|---|---|
| Page One | 45.37 (12.79) | 0.60 (0.68) |
| Page Two | 44.25 (10.11) | 0.75 (1.19) |
| Page Three | 43.52 (9.22) | 0.65 (0.98) |
| Page Four | 43.46 (8.96) | 0.35 (0.75) |

Here, repeated measure ANOVAs show that as far as reaction time goes, there was no effect of page [$F$ (3, 57) = 1.085; $p$ = 0.363 ns.; partial eta squared = 0.054]. In addition, there was no effect on the number of errors made [$F$ (3, 57) = 0.904; $p$ = 0.445 ns.; partial eta squared = 0.045], indicating that a control population responds consistently to the $O^3$ task.

*Selective Attention Task*

Participants reported the Selective Attention task as having a difficulty rating of 2.75 (sd = 1.070) out of five which puts it broadly in line with the others. Due to the fact that the number of each stimulus varied, number of errors made were converted to a percentage scale.

Table 26

*Mean latency and number of errors made, according to stimuli*

| Stimuli | Reaction Time (milliseconds) | Number of errors | Percentage of mistakes (%) |
|---|---|---|---|
| Solo | 601.78 (92.46) | 2.80 (2.55) | 2.24 (2.03) |
| Neutral | 586.23 (94.15) | 2.30 (2.20) | 1.84 (1.76) |
| Congruent | 581.67 (94.09) | 2.10 (1.99) | 1.68 (1.59) |
| Incongruent | 580.17 (88.88) | 1.65 (1.34) | 2.20 (1.79) |

Note: For solo, neutral and congruent stimuli, number of trials (n) = 125; for incongruent stimuli, n = 75.

Repeated measures ANOVAs with stimulus as the independent variable found that type of stimuli had affected reaction time [$F$ (3, 57) = 10.418; $p$ = 0.000; partial eta squared = 0.354]. LSD post hoc tests indicated that solo stimuli promoted a slower response than neutral ($p$ = 0.001), congruent ($p$ = 0.000) or incongruent ($p$ =0.000) stimuli. There were no significant differences between the other categories. In addition, type of stimuli did not affect errors made [$F$ (3, 57) = 0.820; $p$ = 0.488 ns.; partial eta squared = 0.041].

In addition, it remains possible to look at how successful participants were as the task progressed, and whether performance was constant. If performance is not constant, it can be seen whether this is due to a practice effect (gradual improvement) or mental fatigue (gradual decline).

Table 27

*Mean reaction times per individual stimuli and errors made as determined by progression through the Selective Attention task*

| | **Reaction Time (milliseconds)** | **Number of errors** |
|---|---|---|
| Section One (1-90) | 610.08 (126.10) | 1.50 (1.64) |
| Section Two (91-180) | 579.62 (102.96) | 1.75 (1.71) |
| Section Three (181-270) | 583.07 (95.39) | 1.30 (1.13) |
| Section Four (271-360) | 585.21 (92.01) | 2.05 (2.19) |
| Section Five (361-450) | 583.39 (91.24) | 2.25 (2.30) |

Repeated measures ANOVAs showed that progression through the counterbalanced sections did not affect reaction time [$F$ (4, 76) = 1.126; $p$ = 0.311 ns.; partial eta squared = 0.060]. In addition, there was no significant effect of progression on number of errors made [$F$ (4, 76) = 1.388; $p$ = 0.246 ns.; partial eta squared = 0.068]. This indicates performance of the control population was unaffected by task duration.

## Discussion

The results of the State Fatigue Inventory (SFI) show a significant effect of time. As the pilot population progressed through the tasks, they tired. So while the buzzwire may provide a distraction between tasks to ensure that one does not affect the second, it does not provide enough of a break to mitigate the effects of fatigue so apparent on the control population in Study One. As such, the current format is applicable to answer the question left over from Study One; to see if tinnitus sufferers are affected by state fatigue in a different way to a suitable matched control population, i.e. whether their performance is affected both by presence of the tinnitus sensation and task demand.

The Grid task showed that the three different sections of the pilot study were progressively harder, or seen as such; that reaction time was longer and in the case of the longest (final) section, significantly more errors were being made. Granted, this may be due to the fact that a longer task merely promotes more opportunity to make a mistake, but the larger numbers involved make for easier analysis. Clearly, a control group will begin to suffer increasing performance decrement after monitoring the task for a reasonable length of time (up to eight minutes). Since this is the case and, if tinnitus is truly a cognitive distracter, then an experimental population of tinnitus sufferers should perform significantly worse than a matched control group, especially as time goes on. However, it was also decided that three separate sub-sections break up the task unnecessarily. Therefore, for Study Two proper, this will be reduced to two sections; a quick practise session and the task itself. Nevertheless, the missed out second sub-section may very well have had something to do with the main effect of fatigue as measured by the SFI. As such, it is proposed to *merge* sections two and three to create a longer version of the Grid task - 600 items in length. Since this increases overall duration of the task, and that much of the time is simply spent monitoring the screen, it was also decided to slightly decrease the length of time between each stimulus to 750 milliseconds. This would keep the length of the task constant at eight minutes. In addition, this is roughly the amount of time required by the pilot control group to respond. Since care will be taken to ensure that the target letter "b" will not appear twice in succession - indeed, only 5% of the time - this change can be justified to ensure that logical extrapolation is possible.

The results of the Mackworth Clock task (MCT) were very similar. Again, overall performance was reduced furthest in the longest sub-section, the fifteen minute trial. Since more errors were promoted here, it is logical to suggest that tinnitus sufferers will do worse still, as this would be in line with past results. Because of this, it was decided to keep a quick practice session at the start of the MCT before moving onto a larger second session which will effectively be a merger of the remaining two sub-sections. Rather than a three minute session (8 skips) followed immediately by a fifteen minute session (16 skips), it would be more streamlined to have a single twenty minute session containing 20 skips - at long and irregular intervals as before. In addition, this longer yet equivalent task may well have the benefit of promoting more errors as time goes on, as was the case in the original study (Mackworth, 1948).

The Odd One Out ($O^3$) task provided data that showed no practice effect, and that reaction time and error rates are constant. This would be expected as it is tinnitus sufferers alone who perform less well at the rule of letter (page 95). What is certain is that the $O^3$ task provides a steady baseline to which tinnitus sufferers can be compared to matched controls by statistical method.

Analysis of the Selective Attention task shows that it is solo stimuli - i.e. individual letters by themselves - that take significantly longer to respond to than the others, though there was no effect of time. It was noted that response times were slower overall than in Study One (Table 11, page 98). Error rates were fairly constant throughout, for stimuli and across time. Therefore, it can be concluded that a control group will perform consistently in this task, with solo stimuli a little more demanding than the others.

In terms of difficulty, the Grid task would seem a little harder than the others, but not overly so. As such, it is reasonable to expect that they are roughly comparable to each other in terms of task demand. In addition, it is expected that a control group will perform consistently at the $O^3$ and the Selective Attention task, making only a relatively small number of errors. What remains to be seen is the effect of tinnitus on task performance (Study Two). It is expected that tinnitus will also have an distracting effect on the two tasks of sustained attention, and that a tinnitus sample will perform comparatively worse than a matched control group at the $O^3$ - rule of letter - and the Selective Attention task. Noteworthy is the fact that the tinnitus population only responded more slowly than the control population at the OMO and the Selective Attention task, but making the same number of errors. Since the tasks are now more demanding than previously, it will be interesting to note whether this process continues, or whether the tinnitus sample will also make comparatively more mistakes. Finally, it is assumed that the SFI will produce another significant interaction; that the tinnitus group will be more fatigued to begin with, but will tire at a slower rate than the control population.

## STUDY TWO

### Hypotheses

(1) Decrement Hypothesis: A clear and significant performance decrement will exist between the tinnitus population and the matched control group. Furthermore, it will be the tinnitus group that performs comparatively worse.

(2) Cost Hypothesis: The performance decrement will be accompanied by an increase in both perception of task difficulty (on the part of tinnitus sufferers), and by an increase in either tinnitus severity (i.e. distress on the part of the individual), or tinnitus awareness.

(3) Fatigue Hypothesis: Though more fatigued to begin with, the tinnitus population will resist increasing state fatigue more effectively than the match control population.

## Method

### *Participants*

Thirty-six participants volunteered to take part in the second laboratory study. As was the case previously, every effort was made to match each tinnitus sufferer - with regards to both age and gender - to a suitable control. Nineteen participants were female and seventeen were male. Participants were spread equally between the two groups: the tinnitus sufferers (n = 18) and the control group (n = 18). The average age was 40.58 (sd = 14.63), with the tinnitus group (42.39; sd = 14.63) once again being slightly older than the control group (38.78; sd = 13.99). On average, this sample is roughly seven years younger than in the previous study. The criteria for inclusion as a tinnitus sufferer remained the same as before (page 87), yet this time around, a completely different set of participants were used. This was to ensure that performance would not be compromised by over-familiarity with the Selective Attention task and the Odd One Out ($O^3$) task. Again, several tinnitus sufferers were from the Hull Self-Help Tinnitus Support Group (HUSH), but this time, the majority were recruited by way of a campus-based poster and web-based/e-mail campaign. The matched control group - particularly those matching more middle-aged participants - came from their social circles. All participants held English as their first language.

### *Materials (Questionnaires)*

Although fewer questionnaires were carried over into this study, two were still utilised. These were the State Fatigue Inventory (SFI) - which was handed out both before and after the experiment to provide pre- and post-experimental measures - and the Subjective Tinnitus Severity Scale (STSS) which was obviously given only to the tinnitus sample. The rationale behind the use of these questionnaires is broached in detail on pages 79 and 83.

### *Materials (Experiments)*

#### *Grid Task*

This version of the grid task was a further adaptation of the one adopted for the pilot study. The pilot study indicated that as grid size, length and speed increased, the task was perceived as more difficult - resulting in slower response times and more errors - and suggesting that both may be accurate measurements of performance. Rather than running three subsections (e.g. pilot study), it was decided to streamline the task with only one small practice session to orient to the task, followed by a more intensive subsection of 600 stimuli - at a rate of 750 milliseconds per change of stimulus. As such, the whole experiment lasted seven and a half minutes (450 seconds). As before, the target letter "b" appeared 5% of the time. Practically, this meant it appeared a total of thirty times at irregular intervals. Errors - whether false positives or missed responses - were recorded alongside reaction time.

#### *Mackworth Clock Task (variant)*

The Mackworth Clock task was also altered due to the findings of the pilot study and, as with the Grid Task, three sections were thought to be too distracting. The longest section of the pilot study - 15 minutes in length - provided the strongest relationship between subjective difficulty and the number of errors made, and since the aim of the task is to highlight differing performance between tinnitus sufferers and matched controls, the main trial was lengthened by a further five minutes. This time, participants were given a one minute example trial to orient themselves properly before facing the task proper. The task was 20 minutes long, and contained 20 "skips". These averaged one per minute, coming at long and irregular intervals. Both reaction time and number of errors were recorded.

*Odd One Out ($O^3$) Task*

The Odd One Out ($O^3$) task remained the same (page 134), as no change was deemed necessary. The pilot study showed a control group responding consistently throughout, and it was hoped that this would provide a clear-cut baseline to compare tinnitus sufferers against. It was rated by the participants as having a moderate (subjective) level of difficulty and as such is appropriate to provide a contrasting difficulty level to other tasks selected for the study.

*Selective Attention Task*

The Selective Attention Task provided evidence in the original study that task difficulty might well be a factor in determining the performance of tinnitus sufferers. The pilot study determined that the task in its newest form (450 trials) was seen by participants as being of a moderate level of difficulty. It was therefore decided to keep the task as previously described (page 126).

*Procedure*

The procedure of the second study did not vary much from the procedure of the pilot study (page 126). However, a few differences do need mentioning. For example, tinnitus sufferers were participating this time round. In addition, while all participants were asked to rate subjectively the difficulty of the tasks presented to them, tinnitus sufferers were also asked to pay attention to their tinnitus. Obviously, being asked to consciously monitor the tinnitus sensation effectively focuses attention on it, increasing awareness if not technically worsening it. The consent form (Appendix B) was designed to warn tinnitus sufferers than this might be the case and the researcher ensured that participants were well aware that they could retire from the study at any time if they chose to do so. After this was confirmed, tinnitus sufferers were given the Subjective Tinnitus Severity Scale (STSS) to complete. All participants were then shown the format of the rating sheets that they would used to rate difficulty (Appendix B) - and the tinnitus population was also shown the scale required to rate their tinnitus throughout (Appendix B). In addition, it was verbally stressed to the tinnitus sufferers that the scale was with regard to their perception of their tinnitus as compared to normal - i.e. even if their tinnitus was particularly troublesome in general, that a "no louder or quieter than normal" was required when their tinnitus was as it usually is. Once the purpose of these were understood, all participants were asked to fill out the State Fatigue Inventory (SFI) for the pre-experimental measurement and, in addition, the tinnitus group were asked to rate their tinnitus *at that exact moment.* Every participant was then given the four tasks in counterbalanced order. Before each task, participants were handed laminated instructions (as seen in Appendix B) and, afterwards, various measurements were recorded. Between each experiment, participants were given the "buzzwire" in order to reduce crossover of mental fatigue and to aid a more accurate comparison of the results gained from participants taking the tests in a different order. On completion of all tasks, participants were given the SFI again - for their post-experimental measurement - and then thanked for their participation.

# RESULTS

*Subjective Tinnitus Severity Scale (STSS)*

The Subjective Tinnitus Severity Scale (STSS) provided a mean subjective tinnitus rating of 6.78 (sd = 3.93). This is less than that of Study One (7.90; sd = 3.24) and probably to be expected due to the fact that a smaller proportion of the tinnitus sufferers taking part were help-seeking. However, an independent t-test showed that this difference was not significant: $t$ (36) = 0.963; $p$ = 0.342 ns. This time, only four out of the sample of eighteen (22.2%) reported what Halford, Stewart and Andersson (1991) would consider - as clinicians - to be severe tinnitus. As such, the tinnitus sample is again reporting more moderate levels of tinnitus than the established literature.

*State Fatigue Inventory (SFI)*

As stated in the procedure section (page 143), the State Fatigue Inventory (SFI) was given to participants both before ($t_1$) and after ($t_2$) they completed the four tasks.

Table 28

*Descriptive data for the State Fatigue Inventory (SFI); (n = 36)*

| **Timepoint** | **Mean fatigue scores** | | | **Standard deviations** | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| **Before** | 37.44 | 38.28 | 37.86 | 9.06 | 12.67 | 11.05 |
| **After** | 45.50 | 42.06 | 43.78 | 13.41 | 16.16 | 14.81 |

A 2x2 mixed ANOVA investigated possible differences. Group was the independent measure and timepoint the repeated measure. There was a significant effect of time [$F$ (1, 34) = 6.257; $p$ = 0.017; partial eta squared = 0.155], indicating a fatiguing effect; i.e. participants reported greater fatigue on completion than at the start. Nevertheless, no interaction was present [$F$ (1, 34) = 0.818; $p$ = 0.372 ns.; partial eta squared = 0.023], and there was no significant effect of group [$F$ (1, 34) = 0.003; $p$ = 0.958 ns.; partial eta squared = 0.000]. As such, the interaction from Study One was not replicated. The direction of the hypothesis was maintained, namely that the tinnitus group was more fatigued to begin with, yet less fatigued at the end. However, even so, these differences were not significant and the Fatigue Hypothesis must be rejected.

*Ratings (Difficulty)*

As stated in the procedure, all participants were asked to subjectively rate each task. This was on a Likert scale of one (very easy) to five (very difficult).

Table 29

*Subjective difficulty ratings of tasks (n = 36)*

| Task | Mean Rating | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| Grid | 2.78 | 3.72 | 3.25 | 0.88 | 0.89 | 0.99 |
| MCT | 2.40 | 2.51 | 2.46 | 0.86 | 1.24 | 1.06 |
| $O^3$ | 2.56 | 2.84 | 2.70 | 0.92 | 1.02 | 0.97 |
| SAT | 2.94 | 2.94 | 2.94 | 1.06 | 1.21 | 1.12 |

Note: MCT - Mackworth Clock Task; SAT - Selective Attention Task.

A 2x4 mixed ANOVA was used to ascertain not only average difficulty of each task, but also whether the groups differed in how challenging they saw the tasks to be. Group was the independent measure and task the repeated measure. There was a significant overall effect of type of task [$F$ (3, 102) = 3.004; $p$ = 0.034; partial eta squared = 0.081], though no interaction took place [$F$ (3, 102) = 1.533; $p$ = 0.210 ns.; partial eta squared = 0.043]. This indicated the tasks were of varying difficulty. A least significant difference (LSD) post hoc test confirmed the Grid task was seen to be harder; significantly different from both the MCT ($p$ = 0.007) and the $O^3$ ($p$ = 0.017), but not the Selective Attention (SA) task ($p$ = 0.189 ns.). In addition, the MCT was rated differently from the SA ($p$ = 0.044), but not the $O^3$ task ($p$ = 0.491 ns.). In addition, there was no main effect of group [$F$ (1, 34) = 3.971; $p$ = 0.054 ns.; partial eta squared = 0.105] though this tended towards significance. Table Twenty Eight illustrates that the tinnitus sample found the Grid Task more difficult than the control group. It is likely that this one task accounts for most of the difference between the two populations and that the other differences were negligible. As such, there is partial support for the Cost Hypothesis.

*Ratings (Tinnitus)*

Logically, only the tinnitus population (n = 18) were asked to make a judgement as to the severity of their tinnitus during the various stages of the second study. While all four experiments were counterbalanced, Likert ratings out of five (1 = very quiet; 5 = very loud) were asked for at the end of each individual task.

Table 30

*Showing reported tinnitus levels during the experiment (n = 36)*

| Timepoint | Mean ratings (out of 5) | Standard deviations |
|---|---|---|
| Pre-experiment | 2.78 | 0.943 |
| After Grid Task | 3.05 | 1.162 |
| After Mackworth Clock Task | 3.44 | 1.042 |
| After Odd One Out Task | 2.67 | 1.029 |
| After Selective Attention Task | 2.67 | 1.085 |

A repeated measures ANOVA was used to investigate whether the tinnitus sample reported different awareness levels of their tinnitus at different times during the study (i.e. when they were under different levels of cognitive demand). There was an overall effect of task [$F(4, 68) = 3.518$; $p = 0.011$; partial eta squared = 0.171] which means that, overall, the tinnitus population was indeed reporting different levels of tinnitus depending on which task they had just completed. This is better depicted in Figure 11 (page 145).

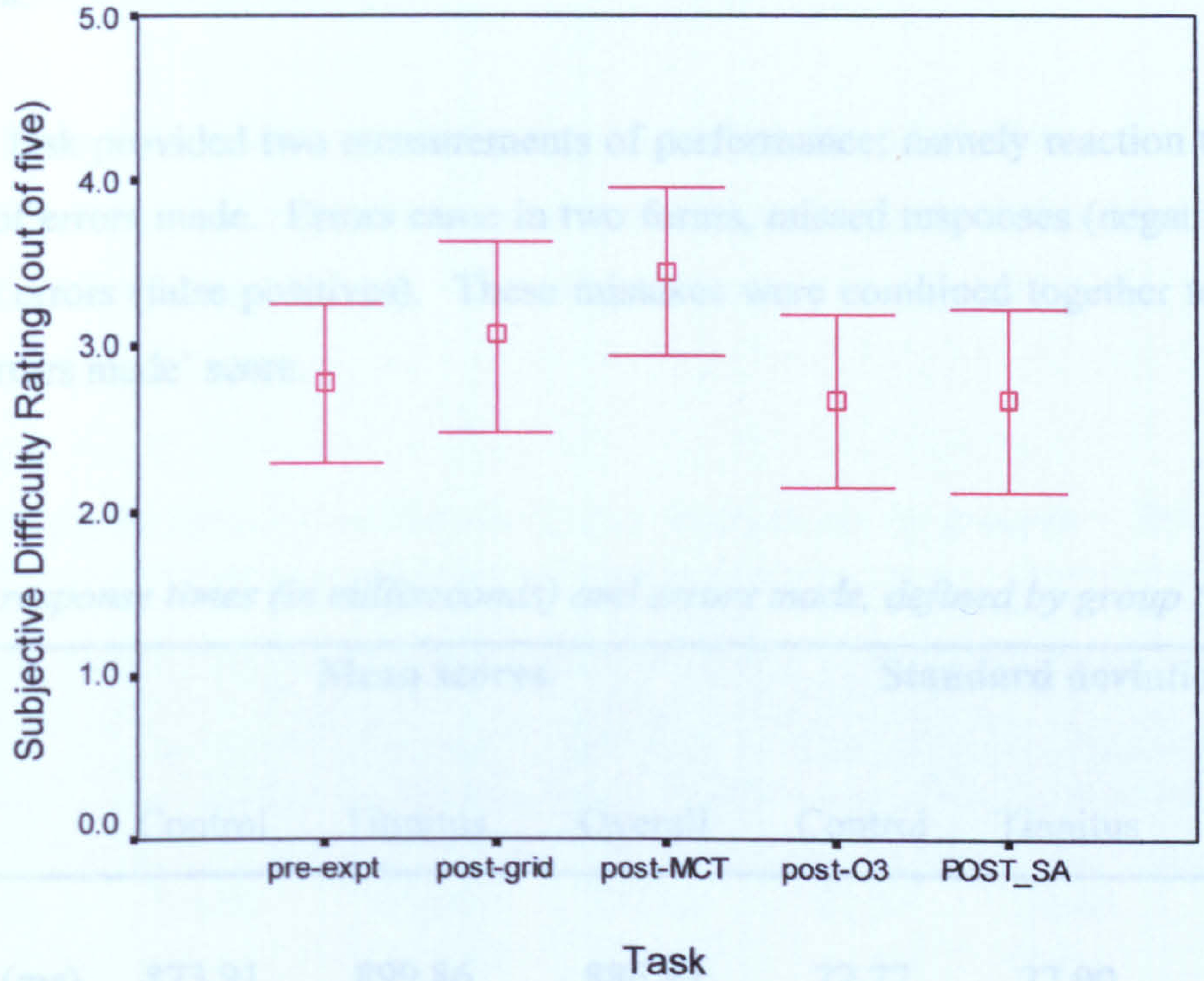



Figure 11: An error bar plot illustrating reported tinnitus levels within different tasks.

This nicely illustrates that tinnitus awareness is at its greatest just after completion of the MCT. Indeed, LSD post hoc tests show this is the case. The ratings of the MCT were significantly different from the ratings before the experiment began ($p = 0.018$); and after the $O^3$ ($p = 0.018$) and selective attention tasks ($p = 0.000$). Interestingly, the only task that does not show a significant difference is the Grid task, which is already known to be the hardest single task. The MCT is considered the easiest task, yet it would appear that something about the MCT is making tinnitus sufferers more aware of their tinnitus than should otherwise be the case. There is partial support here for the Cost Hypothesis, especially on consideration of performance in the individual tasks. [As will be seen, the tinnitus group did significantly worse in both the Grid task and the MCT].

*Grid Task*

The grid task provided two measurements of performance: namely reaction time and number of errors made. Errors came in two forms, missed responses (negatives) and unforced errors (false positives). These mistakes were combined together to form a single 'errors made' score.

Table 31

*Average response times (in milliseconds) and errors made, defined by group (n = 36)*

| | **Mean scores** | | | **Standard deviations** | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| Latency (ms) | 873.91 | 899.86 | 886.89 | 72.77 | 27.90 | 55.88 |
| Errors Made | 1.61 | 4.17 | 2.89 | 2.17 | 4.02 | 3.44 |

While response time and errors made are both measures of performance, it is not really possible to combine them into a single MANOVA. As such, it was decided to investigate differences between the groups with two separate univariate ANOVAs, one for each measure of performance. It was found that there was no effect of tinnitus on reaction time [$F$ (1, 34) = 1.997; $p$ = 0.167 ns.; partial eta squared = 0.055]. However, there was a significant effect of tinnitus on the number of errors that were made [$F$ (1, 34) = 5.633; $p$ = 0.023; partial eta squared = 0.142]. As can be seen from the table, this indicates that tinnitus sufferers clearly made more mistakes, even though reaction times were on a par with the control group. The Decrement Hypothesis - that presence of tinnitus alone can result in poorer performance - is supported.

*Mackworth Clock Task (MCT)*

The MCT was structured in the same way as the Grid Task. Performance was again measured in terms of response time and errors made - negatives and false positives combined to form a total.

Table 32

*Average response times (in milliseconds) and errors made, by group(n = 36)*

| | **Mean scores** | | | **Standard deviations** | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| Latency (ms) | 718.99 | 735.00 | 727.00 | 64.33 | 86.63 | 75.64 |
| Errors Made | 0.78 | 4.28 | 2.53 | 0.88 | 6.03 | 4.60 |

For the same reasons as before, univariate ANOVAs were chosen to ascertain whether the presence of tinnitus resulted in performance decrement with regards to the MCT. Yet again, there was no effect of tinnitus on response times [$F$ (1, 34) = 0.396; $p$ = 0.533 ns.; partial eta squared = 0.012], but there was a real difference in number of errors made [$F$ (1, 34) = 5.943; $p$ = 0.020; partial eta squared = 0.149]. Therefore, we find a similar situation to that of the Grid task; the tinnitus sample is responding at the same speed as their matched controls, but are making more errors. A performance decrement caused by tinnitus is apparent so the Decrement Hypothesis is supported.

*Odd One Out ($O^3$) Task*

The $O^3$ task has remained fundamentally unchanged from the pilot study, consisting of four pages, with only the one rule utilised throughout. Unlike in either the Grid Task or the Clock task - but similar to the Selective Attention task - the $O^3$ requires a response to each and every trial. As such, all responses were either right or wrong, with the number of incorrect responses recorded alongside response time.

Table 33
*Completion times of both tinnitus sufferers and matched controls (n = 36)*

| Page | Mean Completion Times (sec) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| 1st Page | 46.19 | 45.90 | 46.05 | 11.76 | 5.75 | 9.12 |
| 2nd Page | 44.47 | 44.07 | 44.27 | 10.36 | 7.71 | 9.00 |
| 3rd Page | 45.14 | 43.13 | 44.13 | 8.69 | 7.45 | 8.04 |
| 4th Page | 43.37 | 44.25 | 43.80 | 9.69 | 6.64 | 8.19 |

A 2x4 mixed ANOVA was chosen to investigate the effect that the presence of tinnitus might have on response times during the $O^3$ task. As would be expected, group was the independent measure and page number the repeated measure. As previously in Study One, there was an overall effect of page [$F$ (3, 102) = 3.254; $p$ = 0.025; partial eta squared = 0.087] indicating both a slight practice effect and a gradual slowing down due to mental fatigue (see Table Thirty Two). There was no interaction [$F$ (3, 102) = 1.107; $p$ = 0.350 ns.; partial eta squared = 0.032], nor an effect of group on completion times [$F$ (1, 34) = 0.028; $p$ = 0.867 ns.; partial eta squared = 0.001].

Table 34

*Depicting numbers of errors made by the tinnitus group and matched controls (n = 36)*

| Page | Mean Number of Errors made | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| 1st Page | 0.50 | 0.22 | 0.36 | 0.618 | 0.428 | 0.543 |
| 2nd Page | 0.78 | 0.56 | 0.67 | 1.003 | 1.042 | 1.014 |
| 3rd Page | 0.56 | 0.61 | 0.58 | 0.784 | 0.916 | 0.841 |
| 4th Page | 0.61 | 0.22 | 0.42 | 1.037 | 0.428 | 0.806 |

Another 2x4 mixed ANOVA was used to investigate any possible effect that the presence of tinnitus may have on the number of errors made while completing the four pages of the $O^3$. Once again, group was the independent measure with page the repeated measure. No significant effect of page was apparent [$F$ (3, 102) = 1.179; $p$ = 0.332 ns.; partial eta squared = 0.034], and no significant interaction occurred [$F$ (3, 102) = 0.520; $p$ = 0.669 ns.; partial eta squared = 0.015]. In addition, there was no significant effect of experimental group [$F$ (1, 34) = 1.885; $p$ = 0.179 ns.; partial eta squared = 0.053].

In summary, no performance difference exists between tinnitus sufferers and their matched control group on the $O^3$ task. Therefore the Decrement Hypothesis is not supported under these conditions.

*Selective Attention Task (SAT)*

As was previously the case, performance on the selective attention task was considered in terms of response to the different stimuli, and effect of increasing mental fatigue as the experiment progressed. In all cases, response times to the stimuli were recorded, and errors noted.

*Selective Attention response time (by stimulus)*

Table 35

*Which shows group and overall response times for the different stimuli (n = 36)*

| Stimuli | Mean Times (in milliseconds) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| Solo | 636.27 | 657.78 | 646.72 | 71.59 | 97.58 | 84.63 |
| Neutral | 609.95 | 639.17 | 624.14 | 65.76 | 88.57 | 77.92 |
| Congruent | 603.86 | 639.08 | 620.96 | 67.62 | 88.41 | 79.27 |
| Incongruent | 615.63 | 642.18 | 628.53 | 70.20 | 94.66 | 82.84 |

The 2x4 mixed ANOVA incorporated group as the independent measure and type of stimulus faced as the repeated measure. It found a clear-cut effect of stimulus [$F$ (3, 99) = 11.925; $p$ = 0.000; partial eta squared = 0.265], illustrating that each type of stimulus provoked a different speed of response. LSD post hoc tests indicated - as in the pilot study - that solo stimuli provoked slower responses than the other three; whether neutral ($p$ = 0.000), congruent ($p$ = 0.000) or incongruent ($p$ = 0.002). There were no other differences. In addition, there was no interaction [$F$ (3, 99) = 0.742; $p$ = 0.529; partial eta squared = 0.022], nor any significant differences due to group membership [$F$ (1, 33) = 1.099; $p$ = 0.302 ns.; partial eta squared = 0.032].

*Selective Attention response time (across time)*

Table 36:

*Mean times throughout the course of the experiment (n = 36)*

| Block | Mean Times (in milliseconds) | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | **Control** | **Tinnitus** | **Overall** | **Control** | **Tinnitus** | **Overall** |
| First (0-90) | 642.37 | 672.03 | 656.77 | 86.52 | 106.81 | 96.62 |
| Second (91-180) | 596.74 | 622.26 | 609.14 | 71.21 | 99.89 | 86.02 |
| Third (181-270) | 605.78 | 632.02 | 618.52 | 74.96 | 96.03 | 85.59 |
| Fourth (271-360) | 617.35 | 636.52 | 626.66 | 70.30 | 88.78 | 79.21 |
| Fifth (361-450) | 623.86 | 648.84 | 635.99 | 77.67 | 85.49 | 81.33 |

The 2x5 mixed ANOVA was structured in the same way as before, with group the independent variable, whereas the average response time for the randomized blocks was the repeated measure. In this case, Mauchly's Test of Sphericity was significant, requiring the use of Greenhouse-Geisser Epsilon values. As such, there was an expected effect of stimulus [$F$ (4, 136) = 8.455, $p$ = 0.000; partial eta squared = 0.199], with Table Thirty Five showing that after a brief practice effect, response speed slowed. There was no interaction [$F$ (4, 136) = 0.091, $p$ = 0.950 ns.; partial eta squared = 0.514]. Furthermore, there was no significant difference to be found in the performances of the groups [$F$ (1, 34) = 1.015, $p$ = 0.321 ns.; partial eta squared = 0.029], meaning overall response speeds of both populations were comparable.

*Selective Attention error rate (by stimulus)*

As with the pilot, Study Two slightly changed the way in which data is presented. Rather than talk of a mean number of correct responses, the table below points out the mean number of errors made as a percentage of the number of stimuli faced. This is as there were fewer incongruent stimuli (n = 75) than the other three (n = 125), and allows for a more accurate comparison.

Table 37

*Percentage errors made by the two groups - as defined by stimulus (n = 36)*

| Stimuli | Mean (%) of Errors made | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| Solo | 2.93 | 2.87 | 2.90 | 2.92 | 1.33 | 2.23 |
| Neutral | 2.00 | 1.55 | 1.78 | 2.61 | 1.11 | 2.00 |
| Congruent | 1.42 | 2.30 | 1.85 | 2.22 | 2.05 | 2.16 |
| Incongruent | 1.48 | 2.35 | 1.90 | 1.57 | 1.91 | 1.77 |

Another 2x4 mixed ANOVA investigated whether thee tinnitus sensation exerts some sort of effect on error rates during the Selective Attention task, with the added consideration of type of stimulus. Group was the independent variable and type of stimulus the repeated measure. A clear and significant effect of stimuli was discovered but due to the fact that the p-value for Mauchley's Test of Sphericity was significant, Greenhouse-Geisser epsilon values are quoted here [$F$ (3, 102) = 12.618; $p$ = 0.013; partial eta squared = 0.116], showing once again that different stimuli provoke differences in performance levels. LSD post hoc tests showed that this was down to a greater number of errors caused by with solo stimuli; significantly different from neutral ($p$ = 0.000), congruent ($p$ = 0.001) and incongruent ($p$ = 0.039) ones. No other differences existed. There was no significant effect of group [$F$ (1, 34) = 0.219; $p$ = 0.642 ns.; partial eta squared = 0.006], meaning that there was no difference in the performances of tinnitus sufferers and matched controls. In addition, no significant interaction occurred [$F$ (3, 102) = 1.758, $p$ = 0.174 ns.; partial eta squared = 0.051].

*Selective Attention error rate (across time)*

Table 38

*Number of errors made by the tinnitus sample and their matched controls (n = 36)*

| Block | Mean Number of Errors made | | | Standard Deviations | | |
|---|---|---|---|---|---|---|
| | Control | Tinnitus | Overall | Control | Tinnitus | Overall |
| First (0-90) | 1.06 | 1.11 | 1.08 | 2.209 | 1.079 | 1.713 |
| Second (91-180) | 1.56 | 2.11 | 1.83 | 2.121 | 1.844 | 1.978 |
| Third (181-270) | 2.06 | 1.67 | 1.86 | 2.485 | 1.029 | 1.885 |
| Fourth (271-360) | 2.39 | 1.83 | 2.11 | 2.789 | 2.282 | 2.527 |
| Fifth (361-450) | 2.00 | 3.39 | 2.69 | 1.455 | 1.243 | 1.508 |

To look at the effect of the tinnitus sensation on the relationship between error rates and time, a 2x5 mixed ANOVA was required, with group as the independent measure and passage of time (i.e. position the counterbalanced block) the repeated measure. As would be expected, there was a clear effect of time [$F$ (4, 136) = 6.153; $p = 0.000$; partial eta squared = 0.153], indicating a gradual increase in the error rate that can be seen in both Table Thirty Seven and Figure Eleven (page 163). This would suggest the presence of a gradual fatiguing effect. There was no significant main effect of group membership [$F$ (1, 34) = 0.182; $p = 0.672$ ns.; partial eta squared = 0.005], but there was an interaction [$F$ (4, 136) = 2.829, $p = 0.027$; partial eta squared = 0.077].

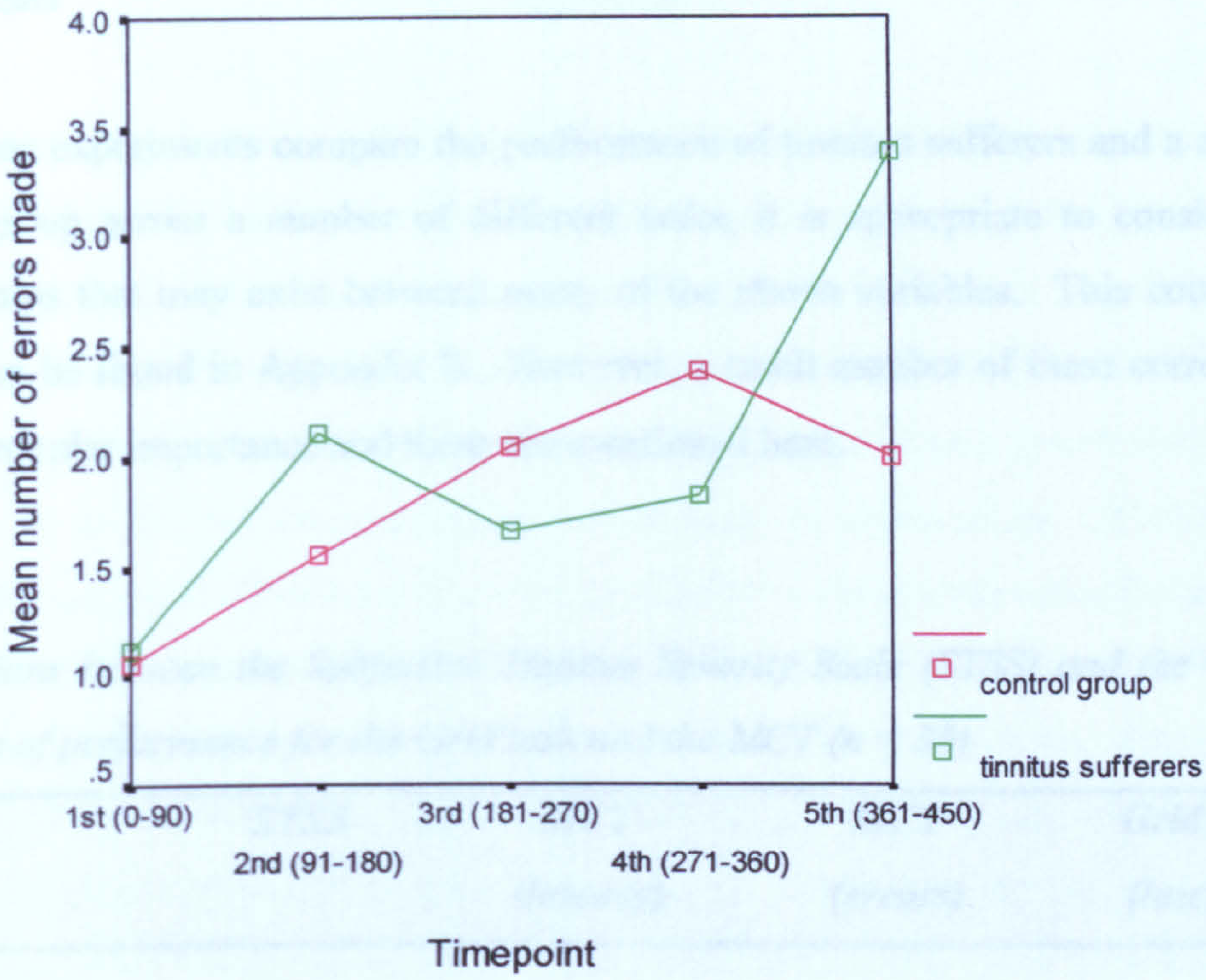



Figure 12: Line graph depicting the changing error rate as time progresses.

The significant interaction can be seen in Figure 12. It shows that error rate increases as time goes on - which would only be expected. It would also appear that with some minor differences, both the tinnitus sample and the control group are making roughly the same number of errors for the majority of the experiment. Nevertheless, in the final (5th) stage, a clear difference becomes apparent; suggesting that tinnitus seems to exert its effect in the final stages of the task, promoting more errors than would otherwise be expected. There is partial support for the Decrement Hypothesis and, in addition, further support for the Cost Hypothesis. Tinnitus sufferers are struggling to maintain performance over an extended period of time.

*Correlations*

Since these experiments compare the performance of tinnitus sufferers and a suitable control group across a number of different tasks, it is appropriate to consider the relationships that may exist between many of the above variables. This correlation matrix can be found in Appendix B. However, a small number of these correlations are of particular importance and these are mentioned here.

Table 39

*Correlations between the Subjective Tinnitus Severity Scale (STSS) and the various measures of performance for the Grid task and the MCT (n = 36)*

| | ***STSS*** | ***MCT (latency)*** | ***MCT (errors)*** | ***Grid task (latency)*** |
|---|---|---|---|---|
| **MCT (Reaction Time)** | .030 | | | |
| **MCT (errors)** | .493* | .215 | | |
| **Grid task (Reaction Time)** | .262 | -.032 | .239 | |
| **Grid Task (Errors)** | .447* | .195 | .500** | .223 |

* $p < 0.05$; ** $p < 0.01$.

Table 39 shows an important correlation matrix. Significant positive correlations exist between STSS scores and number of errors made in both the Grid task and the MCT. As such, participants complaining of more severe tinnitus would appear to make more mistakes. This is in line with the ANOVA findings (pages 146 & 147).

## Discussion

Firstly, - due to practical considerations - this tinnitus sample very slightly smaller than Study One. In addition, this same sample was reporting a subjective level of tinnitus that was less than that found in the majority of the literature. In addition, the subjective levels of tinnitus reported were slightly lower than Study One, but not significantly so. This is not perfect, yet easily understandable since more members of this sample would not have classified themselves as help-seeking. However, as previously suggested (Halford et al., 1991), Subjective Tinnitus Severity Scale (STSS) scores do not differentiate between different levels of tinnitus severity and differences in the vulnerability of the individual to their particular level of tinnitus distress. All things considered, it will be assumed that the original group was perhaps more affected by their tinnitus than these participants. This is due to the fact that the majority of tinnitus sufferers in Study Two were complaining about their tinnitus to the researcher, but were not as actively engaged in seeking ways to alleviate it as were those in Study One (i.e. Study One participants were very active in the local self-help group whereas those in Study Two were not). Yet, these moderate levels of tinnitus severity do have important implications for the study findings. The correlations on page 155 illustrate that participants complaining of more severe tinnitus perform worse than their counterparts so it can be assumed that being more affected by your tinnitus could accentuate any differences found here; it may also bring about further significant differences that did not occur in this particular study. Yet this reduced level of tinnitus severity may mean that conclusions drawn here are more applicable to the majority of chronic tinnitus sufferers - the ones suffering "moderately" but not "severely" so (e.g. Klockhoff & Lindbolm, 1967).

Results for the State Fatigue Inventory (SFI) did not concur with the first study. There was a significant effect of time, indicating that both groups reported increased fatigue at the end of the experiment when compared with scores at the very start - though Table 28 (page 142) illustrates that this fatiguing effect is more apparent in the control population. There were two main differences between Study One and Study Two - setting aside the fact that two tasks were replaced. First is that the tasks were longer and this is probably what produced the main effect of time in this study. Secondly, no interaction took place - forcing the Fatigue Hypothesis to be rejected -

though there is a possibility that this could be due to the use of the buzzwire. Though an effective aid to counterbalancing, the fact that it was introduced for Study Two may have meant that the breaks between tasks ensure greater resistance to fatigue overall, particularly so with the matched control group. However, looking back to the pilot study (Table 22, page 127), a fatiguing effect was observed even with the buzzwire. Hence, it is apparent that the main reason behind the lack of interaction comes from the fact that the two populations are reporting comparable levels of state fatigue at the beginning, something clearly not the case in Study One (page 91). Assuming the original results were not in error, it has been suggested above that this tinnitus sample reported a statistically similar level of tinnitus but was possibly less affected by it, thus eliminating the greatest single reason behind the interaction in Study One. In addition, the matched control group was reporting a much higher initial state fatigue than was the case in the first study - a good ten points worth of difference - indicating that the problem may actually have been a more tired than expected control group, showing that a larger sample size may have been more productive. Technically, the size of the control group was limited by the size of the available experimental (tinnitus) group so it is hard to see how this could have been alleviated without seeking out a larger clinical sample. Still, it is the case that despite the lack of a significant interaction, the results remained similar in the directions that they went. For example, the tinnitus group reported a smaller increase in fatigue on completion of the experiment. Yet differences in both populations were slight and, as such, the effect of tinnitus on state fatigue remains unclear. It may be that without rest, differences between the groups become more apparent. In addition, a tinnitus sample reporting higher overall scores on the STSS may well respond in a similar way to and reinforce the findings of Study One.

In terms of reported difficulty levels (subjective), it would seem clear that the one difference is down to the Grid task. Table 29 (page 143) shows that the tinnitus group reports greater difficulty than the controls. The separate tasks - Grid task notwithstanding - did not provoke any significant differences in perception of difficulty between the populations. What results is the suggestion that some quality of tinnitus interferes with the mental processes required to complete the Grid task. What is also interesting is that tinnitus sufferers only reported increased awareness of their tinnitus sensation on completion of the MCT (page 145). If measurements from the start are taken as a baseline, it would appear that post-$O^3$ and post-SA (Selective Attention) tinnitus perceptions are almost identical to this, meaning that the process of completion does not adversely affect tinnitus severity. Post-Grid ratings - the hardest task (particularly as reported by the tinnitus group) - are a little higher, but not significantly so. Yet the MCT, the easiest task faced, seems uniquely able to provoke a substantial increase in tinnitus awareness. In addition, it must be stated that while the MCT is the only task to provoke such a change in tinnitus awareness, post-Mackworth and post-Grid values are not significantly different from each other. This is most interesting, suggesting that with a sample population reporting more severe tinnitus, both the Grid and Mackworth Clock tasks may provoke similar increases in tinnitus awareness.

The Grid task was new - though piloted previously. As such, it has never been utilised for the purpose of measuring performance of tinnitus sufferers before now. The tinnitus group found it to be more demanding than the controls, so not only were tinnitus sufferers encountering difficulties, but they were aware that this particular task was harder. There was no effect of reaction time, meaning tinnitus sufferers were not taking longer to respond. However, there was a significant difference in the number of mistakes that the two samples made (page 149). It is therefore concluded that the presence of tinnitus was a hindrance to the mental processes required to complete the Grid task, not resulting in a slower response rate, but certainly conducive to increasing numbers of errors made.

Like the Grid task, the Mackworth Clock task was a test of vigilance, requiring speedy responses at specific times. Again, there was no overall effect of group, but the result tended towards significance ($p$ = 0.069 ns.), suggesting the same sort of relationship as with the Grid task. This is supported by the fact that the MCT saw no difference in response times, but had tinnitus sufferers making more errors than matched controls (page 147). As such, both vigilance tasks result in tinnitus sufferers responding at normal speed but with a higher error rate than would be expected. To summarise, the only differences between these tasks are that the tinnitus sample reports significantly greater difficulty on the Grid task, yet reported significantly increased tinnitus awareness on the MCT. The post hocs on page 145 also show no significant difference between the Grid Task and the MCT with regard to tinnitus awareness; the post hocs show that MCT is significantly different from the other tasks only. Post hoc tests (difficulty) show that the MCT was seen as being much easier than the Grid task, but even so, tinnitus sufferers are failing to do as well as their controls. It is very likely that the slow speed of the MCT causes attention to wander. The Grid task is speedier and the movement of the red square inside said grid inspires greater focus. However, it is notable that unlike the other tasks, both demand sustained attention and result in similar findings. The tinnitus group struggled in both scenarios - making more errors - leading to the logical conclusion that the tinnitus sensation interferes with task processing. In the MCT, tinnitus awareness is much increased, suggesting that some of the limited attention resources available were instead subsumed into an increasing awareness of the tinnitus itself, reducing the chances of effective processing. In the Grid task, perception of task difficulty is much higher, and tinnitus awareness not significantly less. Performance still suffers, possibly as mental resources are not quickly reallocated from perception of the tinnitus to the task at hand. Therefore, performance of the tinnitus group is related to task difficulty as well as tinnitus severity, and that it is the interaction of these other factors that leads ultimately to how well tinnitus sufferers perform in comparison to individuals without tinnitus.

As stated in the method (pages 125, 139), the Odd One Out ($O^3$) task had changed since the original study. Originally, tinnitus sufferers were seen to experience a clear performance decrement when faced with the rule of letter. Therefore, it seemed logical to test this rule alone - keeping the format the same - in order to further challenge the tinnitus sample. However, pages 148-149 show that this resulted in no significant differences in performance. There was a practice effect evident, but no significant difference in terms of reaction time or errors made. This was surprising, provoking the asking of just why tinnitus sufferers performed comparably here when the task was supposedly more difficult this time round. There was no difference in length of task (still four pages), so the only difference must be the continuous use of the rule of letter. Since the results of the MCT indicate performance may be affected under less demanding conditions, it is possible that the original OMO task was too easy at first, allowing the allocation of spare resources to the tinnitus sensation and enhancing its power as a distracter. Here, a more difficult $O^3$ variant may well have been challenging enough to require such resources. When the tinnitus sufferer was engaged in the task, most of the available resources focused on that rather than the tinnitus sensation. Clearly, this suggests there comes a point where more resources are needed than can be provided. This suggests that tinnitus, partly though the continuing hypersensitivity of the auditory cortex to specific sounds from the periphery (Mühlnickel et al., 1998), has some quality allowing for the hijacking of unused resources. However, it would follow that when resources are being reallocated to tasks in times of increasing demand, the tinnitus sensation still holds on to some of these finite resources, resulting in reduced performance at earlier timepoints than would be expected of the control population.

The Selective Attention Task (SAT) was similar to the vigilance tasks in that there were no differences in reaction time. When looking at individual stimuli, there was also no difference in number of errors made. This was unexpected as the number of incongruent stimuli present was specifically reduced in order to increase the difficulty of the task - to the detriment of the tinnitus group. A significant effect of stimulus was noted but it was relatively constant, whether tinnitus was present or not. The most interesting result is found where the error rate was studied across time. Even though the main effect of time indicates the error rate began to rise gradually - as would be expected - it is the significant interaction that is most noteworthy. Figure 12 (page 154) shows that it is best to assume no real difference between the two sample population before the fifth and final stage. Here a clear division is apparent, with the tinnitus group making more mistakes than the controls. This is in line with the earlier concept of tinnitus sufferers struggling to utilise every ounce of resource available due to those retained by the auditory cortex. It is also likely that the cost of actively maintaining concentration is beginning to be felt. In addition, it is probable that if the experiment continued, the control group would also begin to make more errors. It is as the tinnitus sample is struggling earlier because less capacity can be brought to bear.

The correlations are interesting. Though no proof of cause and effect, significant relationships with STSS scores only exist for those measures of performance showing a difference between tinnitus sufferers and their matched controls (page 161); i.e. there are moderate and positive correlations between reported tinnitus severity and the errors made in the Grid task and the MCT. It would appear that in these specific areas, tinnitus not only promotes mistakes, but more severe tinnitus promotes even more mistakes. This finding is indicative of tinnitus being a distracting influence as indicated by many earlier studies (e.g. Wilson et al., 1991; Tyler et al., 1992; Attias et al., 1995). However, unlike these studies, here is scientific proof - incorporating a matched control - that clearly illustrates that tinnitus severity is a factor above and beyond the simple presence of the sensation. Simply put, the presence of tinnitus results in a performance decrement for specific tasks, and this decrement increases in the presence of more severe tinnitus. Furthermore, the differences found here may well be clearer and more distinct if the sample measured held the sort of tinnitus levels common to the literature. As has been previously stated, it would be of great academic interest to obtain a tinnitus sample scoring highly on the STSS. Practically though, this turned out to be too difficult and time consuming.

To summarise, these tinnitus sufferers suffered more moderate levels of tinnitus distress than those oft-quoted in the literature. In addition, the expected interaction of the State Fatigue Inventory (SFI) failed to materialise. This may have been due to a failure to completely replicate the original study, but it may also be due to a control group that was more tired than expected. This shows the problems of working with a clinical sample, namely that numbers are smaller than would be preferred. This means that when it comes to fatigue, the situation is not as clear as it could be. So far, this Thesis has hypothesised that tinnitus sufferers are more tired than people without tinnitus, whether it is down to sleep disturbance or the continual mental efforts required to ignore the distraction. This is supported by a wealth of literature (e.g. Erlandsson et al., 1992; Tyler et al., 1992) but has not been shown here. Tinnitus sufferers did not score higher on the General Tiredness Questionnaire (GTQ) in Study One, and the SFI has provided mixed messages. Study One provided a hint of greater anxiety in the tinnitus sample and as such, a less streamlined second study including the Hospital Anxiety Depression Scale may have allowed comparison. Nevertheless, with the information available, it is possible to suggest a new avenue for approach. With a larger sample size, and with the continued use of longer and more demanding tasks, it may be possible to state with greater confidence whether or not individuals with tinnitus are under higher workload than those without - and because of this, they are more resistant to the fatiguing effects of other increases. For now, the Fatigue Hypothesis cannot be supported, but the Decrement Hypothesis is partially supported in specific circumstances. In addition, the Cost Hypothesis is also supported in part.

The tinnitus sample found the Grid task more difficult, and their overall performance was worse than the control group. However, performance was also down on the MCT though it may be that the nature of the task provided limited feedback, resulting in the tinnitus group being unaware that they were missing "skips". Having said that, it is at least as likely that the task simply wasn't very difficult - merely boring. With the limited challenge the MCT appeared to present over a long and extended period of time (twenty minutes), the tinnitus sensation exerted itself. We know this occurred (Figure 11, page 145). It is therefore suggested that it was the *lack* of challenge that resulted in increasing tinnitus awareness and further mistakes. If we consider the correlations (Table 39, page 155), these illustrate that more severe tinnitus enhances problems at hand. This effect did not occur during the $O^3$ task or the Selective Attention task because they were challenging enough to deflect attention, nothing more and nothing less. Unfortunately, this is not borne out by reduced tinnitus awareness (page 145) but it can be argued that as soon as the task is over, the distraction has been removed and tinnitus awareness quickly returns. This links well with the fact that tinnitus masking is only partially effective at best (Wilson et al., 1998) and that tinnitus is quick to reassert itself, and indeed does so over time even if the masking element is constantly increased in volume (Penner, 1983b; Penner 1984). Therefore, it would be very difficult to show that such an effect occurred before the signal reasserts. Difficulty aside, it is true that the tinnitus group only struggled with vigilance tasks. It may be something about the need to monitor stimuli rather than continuously engage with them that is at the root of the performance deficit. Further studies may need to incorporate a number of vigilance studies by themselves - piloted for a variety of difficulty ratings - in order to pinpoint what is occurring.

Of the directions opened up, foremost is the assertion that tinnitus awareness has a more complicated relationship with task difficulty and task performance than previously thought. As such, while aware of the other directions available, this Thesis will concern itself with further investigation of just this one concept. If it is truly the case that performance is affected by tinnitus - as moderated by task demand - then tinnitus sufferers need to rate tinnitus awareness when under a clear spread of demands. This does not lend itself easily to laboratory conditions and so, it was decided to utilise a diary study as the final component of this investigation for both the reasons above and a desire to extend these arguments into real life situations.

## STUDY THREE

### Theoretical Basis

A number of findings from the earlier laboratory studies are of general importance and deserve to be re-iterated. Firstly, while participants held a lower reported level of tinnitus severity, anxiety and depression than that found in the literature, there were no significant differences in trait variables (e.g. mental toughness) between the tinnitus sufferers and the control groups. Study One did note a difference in state fatigue - with tinnitus sufferers reporting higher levels of state fatigue to begin with, but also seemingly unaffected by the fatiguing effects of the experiments that so affected the control group (Figure 7, page 91). This was probably due to the fact that the experiments were not fatiguing enough, so refinements and additions to the Study One experiments resulted in a comparison of the two groups across four experiments in Study Two, with perceived difficulty and reported tinnitus severity noted throughout. The tinnitus group suffered a performance decrement in those tasks perceived as being "easiest" and "hardest", but with comparable performance in the tasks in-between. In addition, reported tinnitus severity was greatest after completion of the easiest of these. Such results drive the idea that demand placed on tinnitus sufferers can determine the level of tinnitus severity perceived by them at that time, and that this in turn can lead to a performance decrement.

Study Two opened up a number of areas for further study - not least by asserting the complicated relationship tinnitus awareness has with task difficulty. It is possible that people suffering from chronic tinnitus struggle with tasks of sustained attention regardless of difficulty - yet the limited resources (e.g. time, space) available to this Thesis and the limitations of the laboratory approach means that a field study is required to expand these ideas further - future research in this direction will be considered in the General Discussion (Chapter Six). For now, since it is logical to assume that a number of factors may have some sort of moderating effect on the relationship; this Thesis will seek to concern itself with investigating task demand and subjective tinnitus severity in a more naturalistic environment. In other words, to monitor changes in tinnitus severity across time, seeing how it fluctuates with regard to other variables. If it is truly the case that demand moderates performance - and is behind the results seen in Study Two - then tinnitus sufferers need to be measured when they are under heavy pressure, a more moderate labour load, and when they are facing few demands on their time. Such a requirement does not lend itself easily to laboratory conditions and so it was decided to press ahead with a diary study as the final component of this investigation. A diary can be an extremely versatile methodological tool which generates a lot of data. It is useful to collect data on a long-term basis and obtain measures on a daily, continuous basis (e.g. Bolger & Schilling, 1991; Marco & Suls, 1993). In addition, information on day-to-day occurrences is not generally captured through the use of questionnaires (Tennen, Suls, & Affleck, 1991). Such information allows for a temporal assessment of measurements over time (Breakwell & Wood, 2000), facilitating a much better and more accurate assessment of the effects of specific variables over time (Larsen & Kasimatis, 1991).

The diary study had several aims, first and foremost to ascertain the immediate factors that help determine tinnitus levels. These aims are stated clearly in the hypothesis section (page 166). It is known and has been well-documented (e.g. Miekle & Taylor-Walsh, 1984; Stouffer & Tyler, 1989) that tinnitus awareness fluctuates during the day. As seen in Study Two, tinnitus awareness can also fluctuate in the immediate aftermath of certain tasks. As such, daily activity is expected to regulate perception of tinnitus severity, if not tinnitus levels themselves. Secondly, it is suggested that other variables (i.e. mental toughness) moderate this interaction. After all, it is known that most but not all participants adapt to their tinnitus over the years (e.g. Hallam, Rachman & Hinchcliffe, 1984; Lewis, Stephens & McKenna, 1994), and that mood is also thought to be a factor (e.g. Sheldrake et al., 1995; Jastreboff et al., 1996; Mirz et al., 1999). Thus, it was proposed that volunteers with chronic tinnitus would complete a six-week diary thrice-daily. This would provide the benefit of having participants report the demands they face and the severity of tinnitus that they are enduring over an extended period of time. By asking for self-report measurements three times a day (i.e. morning/lunchtime/evening) for such a long period of time, it was hoped that this would provide snapshots of participants engaged in a variety of different situations and so cover the full range of demands that they would face during their normal lives. Measurement of a number of other variables alongside immediate demand and severity would allow for investigation of whether such factors are indeed part of the phenomenon - whether these are long-held individual traits (e.g. mental toughness), or other elements of the situation that could affect the burden of demand (e.g. perception of personal performance) in a given scenario. Performance, or in this case a self-reported sense of personal effectiveness may well play a part. A greater sense of effectiveness dealing in whatever has been faced may actually counteract and offset any sense of increased demand.

In addition to this, a diary format allows for the use of a number of data analysis methods. Firstly, many days can be combined to provide accurate averages for each participant. This allows for relevant Analysis of Variance (ANOVA) tests to see if demand - in various forms - has a significant effect on tinnitus severity. Secondly, use of disaggregate data methods allows for each day to be seen as a separate event. This means that many days - provided by each participant - can be brought together. This effectively increases sample size and allows the use of multiple regression analyses to identify whether the expected predictor variables actually determine subjective tinnitus severity.

## Hypotheses

(1) Demand Hypothesis: Different levels of (self-reported) demand will affect tinnitus severity - or perception of tinnitus severity - in the individual.

Note: the structure of the diary allowed measurement of demand in two ways. Firstly, demand was measured as a general concept, one distinct from more immediate demand. This was also investigated in the form of the "last fifteen minutes" questions.

(2) State Demand Hypothesis: Immediate levels of demand will also determine subjective tinnitus severity, as above.

(3) Performance Hypothesis: The earlier studies indicated performance decrements in tinnitus suffers under certain conditions. As such, it is hypothesised that there is a link between subjective tinnitus severity and individual perception of performance.

(4) Moderated Interaction Hypothesis: As a direct link with the laboratory studies, it is predicted that performance of tinnitus sufferers will be affected by different levels of task demand. In other words, it is hypothesised that subjective tinnitus severity and demand will interact to predict performance.

## Method

### *Participants*

Previous participants - from Studies One and Two - were contacted again in the hope that they would take part in this study. In addition, volunteers were solicited from the internet bulletin board set up by the Royal National Institute for Deaf people (RNID) for deaf/hard of hearing people to discuss relevant issues. A total of forty-one people replied positively to first contact. At this stage, all participants were made aware of what was required of them in terms of completing the diary (described in more detail below). Realising this, a total of thirty-two people (78%) still expressed interest and were sent the relevant details. From this group, twenty-four participants (58.5% of total) completed the diary for the required number of weeks and were therefore analysed at the end of this study. All participants were tinnitus sufferers of Grade II or Grade III severity as defined by Klockhoff & Lindbolm (1967), and held English as their first language. Of the twenty-four participants analysed, ten were male and fourteen were female. Their average age was 44.58 years (sd = 16.16), which is consistent with Study One and only slightly older overall than for Study Two. In addition, the participants reported having an average tinnitus duration of 19.09 years (sd = 15.47) - having been asked this question for the first time. Thus, for this variable, no comparison with Studies One and Two is possible.

### *Materials (Trait Questionnaires and Diary)*

A number of questionnaires were utilised in order to measure some specific individual traits. These were the Hospital Anxiety Depression Scale (HADS), the Mental Toughness Questionnaire (MTQ 48) and the Subjective Tinnitus Severity Scale (STSS). All of these questionnaires have been used previously and are described in more detail in Study One - as well as being found in Appendix A.

The diary itself was a more complicated matter. Each day of the diary comprised three pages, coloured coded for: morning (yellow); lunchtime (green); and evening (blue); and then stapled together. A copy of one full day of the diary can be found in Appendix C, along with the instructions for its completion. The morning aspect of the questionnaire began with a nine-point item "How well did you sleep last night?" (1 = slept poorly/ 9 = very well). This was followed by an open-ended question asking for the total number of hours slept. Answers would then be rounded up or down to the nearest half-hour for data entry. Further, participants were then asked "How would you describe your tinnitus LAST NIGHT as you were trying to sleep?" on the same scale as Study Two - Appendix B (1 = very quiet/5 = very loud).

At this point, all three aspects of the diary ask the same questions. The first question common to all three aspects was "How would you describe your tinnitus AT THIS VERY MOMENT?", meaning that participants had to provide a subjective answer on their immediate tinnitus on the same five-point scale. Following this were the six present mood items from the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). PANAS is known to be psychometrically sound (Watson et al., 1988) and was originally developed to allow the simultaneous use of both positive and negative mood ratings. Here though, only the six present mood items were used in order to allow for a clearer set of questions that could be completed easily and at speed. These six items, all scored on a nine-point Likert scale were: enthusiastic/miserable; weary/lively; relaxed/tense; depressed/optimistic; energetic/tired; and on edge/at ease.

There followed a larger section which contained a further eight questions, all based on the same nine-point Likert scale (1 = lowest; 9 = highest). These were taken directly from a study of patterns of work strain and well-being in nurses (Gervais, 2002), and measured: emotional demands; mental demands; physical demands; level of personal control experienced; levels of personal support experienced; effectiveness in getting things done; effectiveness in getting on well with others; and effectiveness in taking care of your own needs. These were utilised in order to assess demand, control and performance levels. As will be seen, demand and personal performance form the main lines of the Study Three hypotheses. However, the two measurements of personal control were eventually discounted in the results analysis to ensure that the main points of discussion were not diluted.

Next came three five-point items asking about the most recent demands on the individual. These were: "How much concentration has been required in the last fifteen minutes?"; "How much effort has been demanded of you in the last fifteen minutes?"; and "How much time pressure have you been under in the last fifteen minutes?" (1 = none whatsoever; 5 = intense). This was then followed by another open-ended question "Briefly, what have you been up to in the last fifteen minutes?" in order to quantify the previous answers in a way providing more specific information about what was happening and what pressures - or not - the participant was under at that time. Finally, the evening sub-section of the diary had one extra question "How would you describe your tinnitus OVERALL, during the course of the day?", a question designed to grant an overall sense of tinnitus separate from the three specific timepoints already looked at. Again, the usual five-point Likert scale was utilised.

*Procedure*

As stated in the participants section, a number of people were canvassed in order to provide as large a clinical sample as possible for the full six weeks of the study. These people were sent their diary in batches as it was felt that being handed forty-two daily diaries - 126 pages - in one go would be off-putting and would affect completion rates. In addition, it was realised that if they were sent out in smaller numbers, it would encourage completion and allow diary pages to be returned on a weekly basis. This granted the added advantages of both facilitating the speed of data input, and allowed more rapid identification of participants who were not complying with the instructions - thus allowing quick interventions to be made via telephone and e-mail to encourage completion of the diary. The first batch of the diary contained the assembled instructions, the various trait questionnaires and the first seven days, along with a SAE to return them to the author. From then on, another week of diary was dispatched every seven days until completion. It was decided that since many participants had no previous experience of such a tool, the first week of the diary was to be set aside, its purpose to allow the participants to get used to filling in the diary as part of their daily routine. In addition, six weeks is a long time and as such, a notable reduction in completion rates was noted in the final week of the study. Therefore, the sixth week was also dropped, leaving the middle 28 days for analysis.

## Results

As will be seen, the diaries provided a vast quantity of data capable of been analysed in numerous ways. For this reason, the results of Study Three will be approached in two distinct ways: as aggregate data and as disaggregate data.

### *Aggregate Data -Results*

For the aggregate data set, each day of weeks two through five (day 8 - day 35) were brought together to create an average score for each of the 37 items per participant. These 37 items were collapsed down from the original 57 items (see Appendix C) to simplify the process and reduce the number of available variables into a more manageable number. Several items from the Positive and Negative Affect Scale (PANAS; Watson, Clark & Tellegen, 1988) were thus collapsed together as suggested by the authors: with the enthusiastic/miserable and depressed/optimistic items averaged to create a single "Enthusiastic" variable; the same process was used to collapse the weary/lively and energetic/tired items into "Lively"; and the relaxed/tense and on edge/at ease items into "Relaxed". The purpose of this was to simplify the process while at the same time maintaining a number of different mood dimensions in he hope that some/all of these would be relevant to tinnitus production. However, during data analysis, it was decided to drop PANAS and concentrate purely on the four hypotheses (page 166). In addition, the three emotional, mental and physical demand items were collapsed into an overall "Demands" score and the three effective items (effectiveness getting things done, effectiveness getting on with others, and effectiveness taking care of own needs) were brought together to create an average termed simply "Effectiveness". This was done for each time of day: morning; afternoon; and evening. For each participant, all twenty-eight daily values were brought together in a combined average and considered alongside trait scores.

*Trait Scores*

Table 40
*Trait scores for diary participants (n = 24)*

| Trait Variable | Means (Standard Deviations) |
|---|---|
| Tinnitus Duration (in years) | 19.09 (15.50) |
| Subjective Tinnitus Severity Scale (STSS) | 7.42 (3.05) |
| Anxiety (HADS) | 6.33 (3.83) |
| Depression (HADS) | 3.96 (3.87) |
| Overall Mental Toughness (MTQ48) | 167.83 (25.47) |

In the strictest sense, tinnitus duration is not a trait. However, it is measured in years and across the six weeks of the study, it remains constant and can be considered stable in this context. Table 40 shows us that reported tinnitus severity (STSS) is comparable to the previous studies (pages 91 and 144) - as supported by a univariate ANOVA showing no significant differences [$F$ (2, 62) = 0.522; $p$ = 0.596 ns.; partial eta squared = 0.017]. In addition, results of the Anxiety and Depression subscales (HADS) and the MTQ48 are similar to values reported by the tinnitus sample in Study One (page 92), confirmed by independent t-tests: anxiety $t$ (42) = 1.070, $p$ = 0.291 ns.; depression $t$ (42) = 0.037, $p$ = 0.970 ns.; and mental toughness $t$ (42) = 0.325, $p$ = 0.747 ns. As such, in terms of the trait values measured, this sample is comparable to the previous ones.

Table 41

*Correlation matrix of relevant variables (n = 24)*

| Variables | AGE | Gender | Duration (years) | STSS | ANX | DEP | MTQ48 | TIN (morn) | TIN (lunch) | TIN (eve) | TIN (overall) | DEM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gender** | -.161 | | | | | | | | | | | |
| **Duration** | .153 | .175 | | | | | | | | | | |
| **STSS** | -.016 | .005 | -.237 | | | | | | | | | |
| **Anxiety** | -.449* | .368 | -.187 | -.333 | | | | | | | | |
| **Depression** | -.128 | -.009 | -.107 | -.190 | .590** | | | | | | | |
| **MTQ48** | .461* | -.192 | .103 | .197 | -.517** | -.381 | | | | | | |
| **Tinnitus (morn)** | .355 | -.010 | .010 | .062 | -.070 | .186 | .553** | | | | | |
| **Tinnitus (lunch)** | .287 | -.021 | -.163 | .457* | -.264 | -.127 | .700** | .756** | | | | |
| **Tinnitus (evening)** | -.003 | -.017 | -.741** | .462* | .039 | .026 | .259 | .410* | .698** | | | |
| **Overall Tinnitus** | .049 | -.015 | -.480* | .561** | -.094 | -.065 | .407* | .575** | .875** | .896** | | |
| **Demand** | -.214 | .265 | .082 | -.020 | .294 | .147 | .050 | .081 | .111 | -.023 | -.001 | |
| **Effectiveness** | .277 | -.020 | -.063 | .039 | -.258 | -.575** | .475* | .051 | .212 | .038 | .041 | .198 |

* $p < 0.05$; ** $p < 0.01$.

Looking at the correlation matrix (page 172), there was a high correlation between mental toughness and anxiety, which is what would be expected to occur. Furthermore, there is an increasing link between subjective tinnitus (STSS) and reported tinnitus severity as the day goes on. Since the STSS is itself a self-measure of tinnitus distress in general, it is reassuring that such correlations are apparent. What is notable is that personal perception of general tinnitus levels do not correlate with self-reports of tinnitus levels in the morning. This may be as the morning is slightly different, affected by the night before - sleep patterns and so on. Interestingly, higher mental toughness scores result in higher reported tinnitus severity in all but the evening severity measure. This is not easily explained, but it may be that mentally "tougher" people, being more willing to either face up to the problem or possibly even to overstate it, are able to cope with tinnitus better. In addition, there is no visible correlation between tinnitus severity and the demand and performance measures.

Note: High correlations exist between the four measures of tinnitus severity. Since these items ask how the currently perceived tinnitus sensation relates to the normal experience, it is important to consider the spread of these scores.

Table 42

*Means and Standard Deviations for the Measures of Tinnitus Severity (n = 24)*

| Tinnitus Measure | Means (Standard Deviations) |
|---|---|
| Morning | 2.99 (0.292) |
| Lunchtime | 2.94 (0.249) |
| Evening | 2.93 (0.433) |
| Overall | 2.98 (0.322) |

As we can see, mean values stay remarkably close to the middling value of '3' - "No louder or quieter than normal". This indicates that response bias is absent, and that the participants are tending to report average subjective severity rather than an extreme.

*The Demand Hypothesis (Overall Demand)*

As stated previously, the earlier studies have suggested that current level of demand may affect severity of tinnitus perceived by the individual at that time. Therefore, levels of demand - subjective - for each time of day were split into three categories (low, medium, and high) by use of frequency percentiles (in SPSS). They were then analysed separately to look for significant effects on reported tinnitus levels.

*Morning Demands*

Table 43

*Means and standard deviations of subjective tinnitus levels, as defined by morning demand (n = 24)*

| | **Overall level of demand (morning)** | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (morning)** | 2.97 | 3.01 | 2.99 | .222 | .327 | .293 |
| **Tinnitus level (lunchtime)** | 2.95 | 2.92 | 2.95 | .317 | .226 | .227 |
| **Tinnitus level (evening)** | 3.01 | 2.77 | 3.01 | .412 | .617 | .263 |

With the participants reporting their tinnitus at several times during the day, it was decided to make use of a 3x3 mixed ANOVA, with demand (morning) as the independent variable and three measurements of tinnitus throughout the day as the repeated measure. This showed no significant main effect of demand on tinnitus severity [$F$ (2, 21) = 0.179; $p$ = 0.837 ns.; partial eta squared = 0.017]. In addition, there was no significant effect of time of day on tinnitus severity [$F$ (2, 42) = 0.517;

$p = 0.700$ ns.; partial eta squared = 0.022], nor any sort of interaction between the two [$F$ (4, 42) = 0.949; $p = 0.455$ ns.; partial eta squared = 0.083]. Note: in the case of time of day, Mauchley's Test of Sphericity was significant so Greenhouse-Geisser epsilon values were quoted instead. From these results, it is suggested that morning demand levels (overall) - as reported by participants - do not affect tinnitus severity during the day.

*Lunchtime Demands*

Table 44

*Mean tinnitus levels, as determined by level of lunchtime demand (n = 24)*

| | **Overall level of demand (lunchtime)** | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (lunchtime)** | 2.93 | 2.94 | 2.96 | .249 | .265 | .268 |
| **Tinnitus level (evening)** | 2.93 | 3.11 | 2.77 | .309 | .321 | .593 |

It is noted that analysing lunchtime demands for an effect on morning tinnitus severity makes no conceptual sense. Therefore, though this 3x2 mixed ANOVA retained three levels of demand (lunchtime) as its independent variable, the repeated measure was made up of the two self-reported tinnitus measures from lunchtime and evening. There was no significant effect of demand [$F$ (2, 21) = 0.475; $p = 0.628$ ns.; partial eta squared = 0.043], nor time of day on severity [$F$ (1, 21) = 0.002; $p = 0.964$ ns.; partial eta squared = 0.000] - though again, Greenhouse-Geisser epsilon values are quoted. Further, no significant interaction was reported though it did tend towards significance [$F$ (2, 21) = 3.107; $p = 0.066$ ns.; partial eta squared = 0.208] and has a large effect size, indicating that the interaction counted for 20.8% of overall variance.

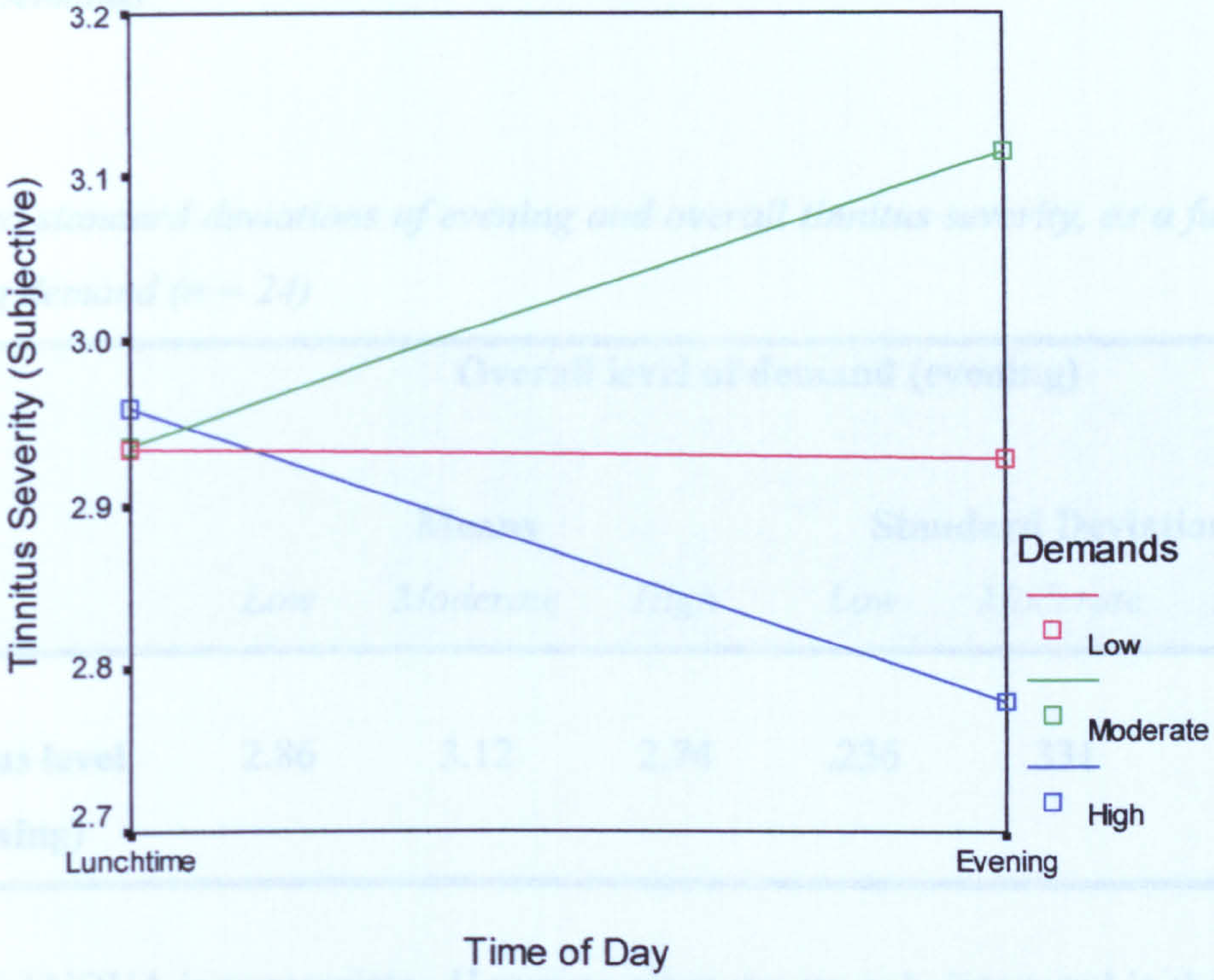



Figure 13: Interaction between time of day and lunchtime demands.

Importantly, the results above do not offer proof of lunchtime demands affecting tinnitus severity. However, as will be seen in context later, Figure 13 illustrates a trend of moderate levels of demand (lunchtime) leading to higher reported levels of tinnitus awareness than low/high levels of demand - an incident repeated on a number of occasions below. Therefore, it is worthy of mention here, even though the interaction was not significant [$p = 0.066$ ns.].

*Evening Demands*

Table 45

*Means and standard deviations of evening and overall tinnitus severity, as a function of evening demand (n = 24)*

| | Overall level of demand (evening) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (evening)** | 2.86 | 3.12 | 2.74 | .236 | .331 | .558 |

Again, an ANOVA is appropriate. However, since we are only interested in the effect of evening demand on evening tinnitus severity levels, there is no repeated measure present. Instead, a univariate ANOVA is appropriate, with demand being the independent variable and tinnitus severity (evening) being the dependant variable. This also showed no significant main effect of demand, though it did tend towards significance [$F$ (2, 21) = 2.785; $p$ = 0.085 ns.; partial eta squared = 0.210]. This shows the possibility of a distinction existing between moderate and high/low demand for tinnitus sufferers.

In addition to this, it is appropriate to consider overall tinnitus ratings for the day. However, this requires the creation of an overall demand variable - produced though an averaging of reported demands throughout the day (morning/lunchtime/evening).

*Overall Demands*

Table 46

*Means and standard deviations of overall tinnitus levels, as determined by average demand levels (n = 24)*

| | Overall level of demand | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Overall Tinnitus severity** | 2.98 | 3.07 | 2.88 | .291 | .297 | .322 |

In a similar vein to the investigation of evening demand, a univariate ANOVA is required, with overall demand as the independent variable and overall tinnitus severity as the only dependent variable. There was no significant effect of overall demand found [$F(2, 21) = 0.620$; $p = 0.547$ ns.; partial eta squared = 0.056].

From the four ANOVAs undertaken so far (pages 174-178), it would seem that there is no effect of demand on tinnitus severity as would have been expected. Nevertheless, there was a tendency towards an interaction between lunchtime demands and time of day, and a suggestion of a trend with regards to the possible effect of evening demands on evening tinnitus levels. As such, this is not the end of the story. While no support is found here for hypothesis one, the demand variables were themselves an amalgamation of three others: namely emotional, mental, and physical demands. These variables will now be looked at separately to investigate whether any of these play a part in determining individual tinnitus severity.

*The Demand Hypothesis (Emotional demands)*

*Morning Emotional demands*

Table 47

*Tinnitus levels, as determined by morning emotional demands (n = 24)*

| | **Emotional demands (morning)** | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (morning)** | 2.97 | 2.98 | 3.02 | .333 | .258 | .321 |
| **Tinnitus level (lunchtime)** | 2.99 | 2.88 | 2.96 | .301 | .248 | .211 |
| **Tinnitus level (evening)** | 3.05 | 2.93 | 2.82 | .363 | .343 | .580 |

A 3x3 mixed ANOVA found no main effect of emotional demand on tinnitus severity [$F$ (2, 21) = 0.152; $p$ = 0.860 ns.; partial eta squared = 0.014]. There was no effect of time of day [$F$ (2, 42) = 0.360; $p$ = 0.700 ns.; partial eta squared = 0.017] and furthermore, no significant interaction between them [$F$ (4, 42) = 0.860; $p$ = 0.496 ns.; partial eta squared = 0.076], which indicates that morning emotional demands do not impact on tinnitus levels.

*Lunchtime Emotional demands*

Table 48

*Reported tinnitus as determined by emotional demand at lunchtime (n = 24)*

| | Emotional demands (lunchtime) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (lunchtime)** | 2.98 | 2.84 | 3.00 | .192 | .287 | .257 |
| **Tinnitus level (evening)** | 3.02 | 2.88 | 2.92 | .218 | .389 | .636 |

Looking at the effects of lunchtime emotional demands required the use of a 3x2 mixed ANOVA. There was no significant main effect of lunchtime emotional demands [$F$ (2, 21) = 0.425; $p$ = 0.660 ns.; partial eta squared = 0.039], no effect of time of day on tinnitus severity [$F$ (1, 21) = 0.02; $p$ = 0.968 ns.; partial eta squared = 0.000] and no interaction to be seen [$F$ (2, 21) = 0.328; $p$ = 0.724 ns.; partial eta squared = 0.030]. As such, any thought of lunchtime emotional demands having an effect on tinnitus severity must be discounted.

*Evening Emotional demands*

Table 49

*Evening tinnitus severity as a function of emotional demand (n = 24)*

| | Emotional demands (evening) | | | | | |
|---|---|---|---|---|---|---|
| | Means | | | Standard Deviations | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (evening)** | 2.92 | 3.10 | 2.80 | .285 | .385 | .581 |

As was previously the case, looking at evening demands only means that no repeated measure is present. Therefore, a univariate ANOVA was chosen, with evening emotional demand as the independent variable and evening (tinnitus severity) as the lone dependent variable. No significant effect was noted [$F$ (2, 21) = 0.860; $p$ = 0.438 ns.; partial eta squared = 0.076], indicating that evening emotional demands do not affect awareness of tinnitus in the evening.

*Overall Emotional demands*

Table 50

*Overall tinnitus scores as determined by mean emotional demand (n = 24)*

| | Overall Emotional demands | | | | | |
|---|---|---|---|---|---|---|
| | Means | | | Standard Deviations | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Overall Tinnitus severity** | 3.05 | 2.93 | 2.96 | .376 | .217 | .398 |

Investigation of the effect that overall levels of emotional demand during the day had on overall tinnitus severity saw an univariate ANOVA find no significant main effect [$F$ (2, 21) = 0.346; $p$ = 0.071 ns.; partial eta squared = 0.032].

From these results, it appears that emotional demands do not affect perception of the tinnitus sensation. The emotional aspect of the Demand Hypothesis can be safely rejected.

*The Demand Hypothesis (Mental demands)*

*Morning Mental demands*

Table 51

*Means and standard deviations for tinnitus severity, as a function of morning mental demand (n = 24)*

| | Mental demands (morning) | | | | | |
|---|---|---|---|---|---|---|
| | Means | | | Standard Deviations | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (morning)** | 2.93 | 2.97 | 3.05 | .227 | .361 | .310 |
| **Tinnitus level (lunchtime)** | 2.83 | 3.06 | 2.94 | .199 | .321 | .199 |
| **Tinnitus level (evening)** | 2.56 | 3.17 | 3.01 | .503 | .363 | .242 |

The possible effect of morning mental demand on tinnitus severity was investigated with a 3x3 mixed ANOVA. This did not show a significant main effect of morning mental demand levels [$F$ (2, 21) = 2.504; $p$ = 0.106; partial eta squared = 0.193]. In addition to this, there was no effect of time of day [$F$ (2, 42) = 0.942; $p$ = 0.398 ns.; partial eta squared = 0.043] but there was a highly significant interaction between the two of them [$F$ (4, 42) = 3.644; $p$ = 0.012; partial eta squared = 0.258].

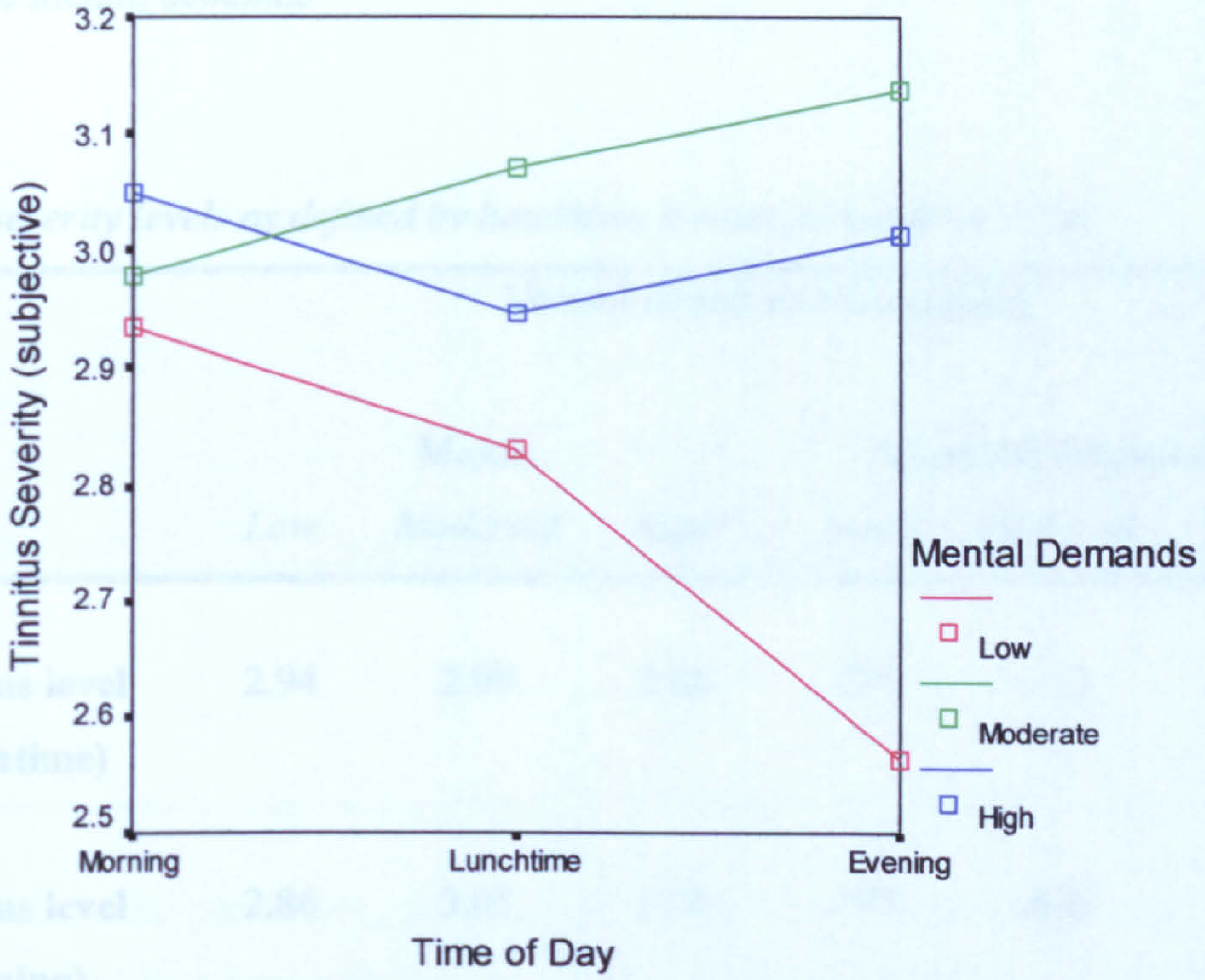



Figure 14: Interaction between morning mental demand and time of day.

Figure 14 shows that while morning mental demand does not affect subjective tinnitus severity (morning), it does have a delayed effect - as can be seen in the big drop in evening tinnitus severity for low demands (red line). It would seem that those participants requiring less mental effort in the morning accordingly report reduced tinnitus awareness in the evening. This indicates support for the demand hypothesis - specifically mental demands. In addition, it fits very well with the concept of increasing mental demand instigating more severe tinnitus, or perhaps, greater awareness of an unchanging tinnitus sensation. And that this in turn will begin to affect performance in specific mental tasks.

*Lunchtime Mental demands*

Table 52

*Tinnitus severity levels as defined by lunchtime mental demands (n = 24)*

| | Mental demands (lunchtime) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (lunchtime)** | 2.94 | 2.99 | 2.88 | .239 | .313 | .176 |
| **Tinnitus level (evening)** | 2.86 | 3.05 | 2.74 | .295 | .408 | .613 |

Again, common sense ensures that morning tinnitus severity will be unaffected by lunchtime mental demands and as such, it will not be considered here. Instead, a 3x2 mixed ANOVA tested the hypothesis. There was no main effect of mental demand [$F$ (2, 21) = 0.873; $p$ = 0.432 ns.; partial eta squared = 0.077], no significant effect of time of day [$F$ (1, 21) = 0.593; $p$ = 0.450 ns.; partial eta squared = 0.027], and in addition, no interaction [$F$ (2, 21) = 0.717; $p$ = 0.500 ns.; partial eta squared = 0.064]. Therefore, any possible effects of lunchtime mental demands must be discounted.

*Evening Mental demands*

Table 53

*Evening tinnitus severity as a result of prevalent mental demands (n = 24)*

| | Mental demands (evening) | | | | | |
|---|---|---|---|---|---|---|
| | Means | | | Standard Deviations | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (evening)** | 2.55 | 3.00 | 3.17 | .474 | .234 | .350 |

As has been seen previously, no repeated measure is possible with the evening measurements as data from only the one timepoint is available for analysis. Therefore, a single univariate ANOVA was utilised, with levels of evening mental demand as the independent variable and self-reported evening tinnitus levels as the single dependent variable. A significant main effect of mental demand was present [$F$ (2, 21) = 6.428; $p$ = 0.007; partial eta squared = 0.380].

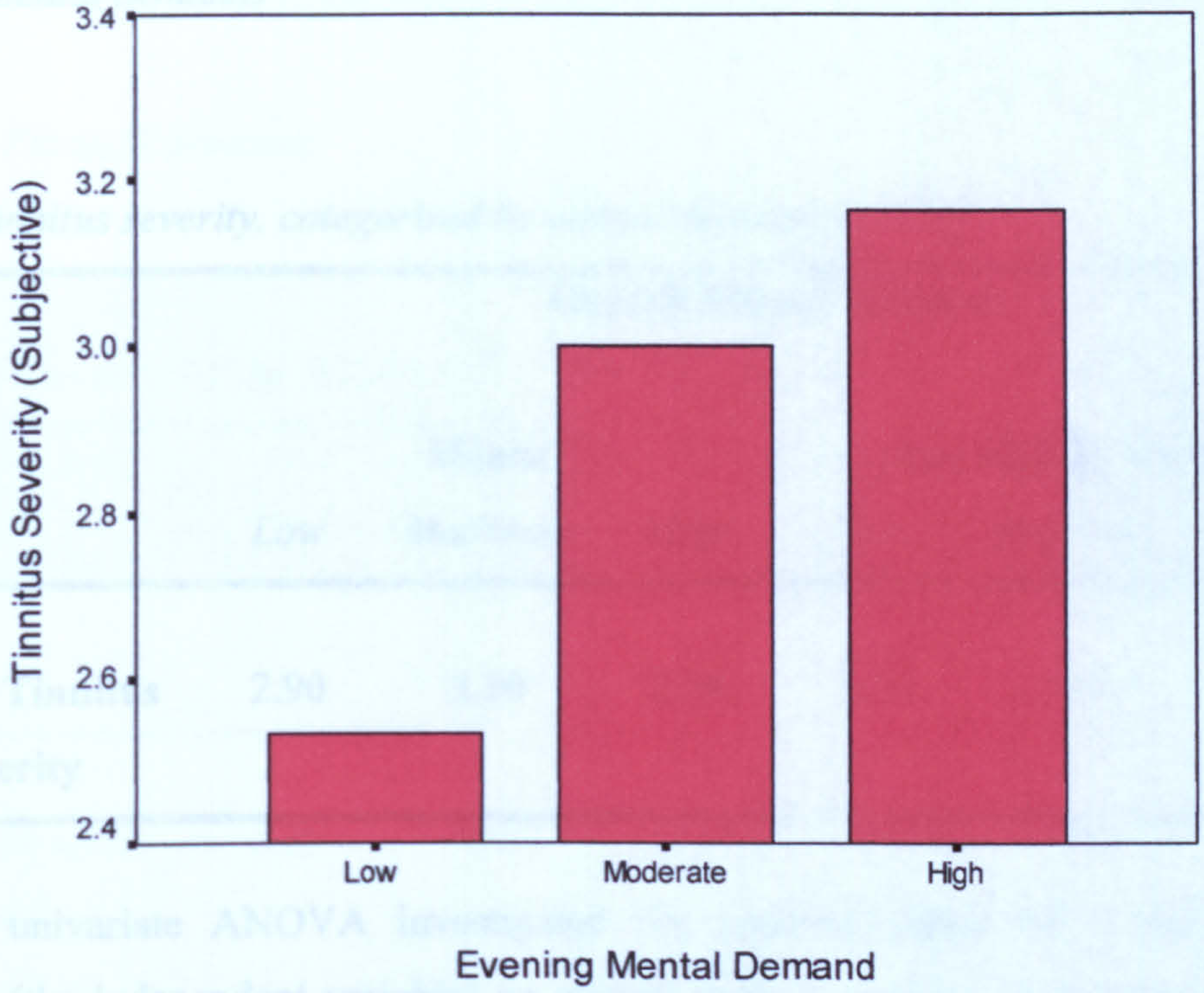



Figure 15: Evening severity levels, as determined by mental demand.

From these results, a Least Significant Differences post hoc test showed significant differences between low levels of mental demand and both moderate ($p = 0.019$) and high levels ($p = 0.002$). There was no difference to be found between moderate and high demands ($p = 0.310$ ns.). Figure 15 is similar to Figure 14 (page 184) in that a significant end of day distinction exists between a low mental demand (less tinnitus distress) and moderate/high mental demand (more tinnitus distress).

*Overall Mental demands*

Table 54

*Overall tinnitus severity, categorised by mental demand (n = 24)*

| | Overall Mental demands | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Overall Tinnitus Severity** | 2.90 | 3.10 | 2.94 | .213 | .461 | .241 |

Another univariate ANOVA investigated the possible effect of overall mental demands (the independent variable) on overall tinnitus severity as reported daily in the diary. No significant effect was found [$F$ (2, 21) = 0.824; $p$ = 0.452 ns; partial eta squared = 0.073].

In summary, taking mental demands separately produced far more substantial effects on tinnitus severity than overall demands did. There was a clear and distinct interaction (page 184) between morning mental demands and time of day - a sure sign that morning mental demand levels have a stronger effect as the day progresses. There was no effect of lunchtime mental demands but there was a clear effect of evening demand: low demand leads to lower self-reported tinnitus severity levels. There was no overall effect, but in general, it has been seen that mental demands do have an effect on tinnitus awareness – as with Study Two. As such - with it being discussed in more detail later on - the Mental Demand Hypothesis will be generally accepted.

*The Demand Hypothesis (Physical demands)*

*Morning Physical demands*

Table 55

*Mean tinnitus severity, as determined by morning physical demand (n = 24)*

| | Physical demands (morning) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (morning)** | 2.89 | 3.01 | 2.99 | .219 | .347 | .296 |
| **Tinnitus level (lunchtime)** | 2.90 | 2.97 | 2.96 | .314 | .172 | .269 |
| **Tinnitus level (evening)** | 3.00 | 3.07 | 2.75 | .416 | .210 | .581 |

Utilising a 3x3 mixed ANOVA to investigate the physical demands hypothesis, there was no main effect of physical demands on tinnitus severity [$F$ (2, 21) = 0.582; $p$ = 0.568 ns.; partial eta squared = 0.053]. In addition, there was no effect of time of day [$F$ (2, 42) = 0.395; $p$ = 0.676 ns.; partial eta squared = 0.018] and no significant interaction [$F$ (4, 42) = 1.972; $p$ = 0.116 ns.; partial eta squared = 0.158]. Therefore, any possible effects of physical demand on tinnitus severity must be discounted.

*Lunchtime Physical demands*

Table 56

*Tinnitus severity levels as a result of lunchtime physical demand (n = 24)*

| | Physical demands (lunchtime) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (lunchtime)** | 2.90 | 2.97 | 2.96 | .329 | .146 | .268 |
| **Tinnitus level (evening)** | 2.98 | 3.06 | 2.77 | .432 | .160 | .593 |

The effect of lunchtime physical demands on self-reported tinnitus severity levels was investigated with a 3x2 mixed ANOVA; with level of physical demand as the independent measure and the repeated measure being the three times of day when tinnitus levels were measured. This ANOVA showed no significant main effect of lunchtime physical demands on tinnitus severity [$F$ (2, 21) = 0.404; $p$ = 0.673 ns.; partial eta squared = 0.037]. In addition, there was no main effect of time of day [$F$ (2, 42) = 0.002; $p$ = 0.965 ns.; partial eta squared = 0.000] and, beyond that, no interaction [$F$ (4, 42) = 2.122; $p$ = 0.145 ns.; partial eta squared = 0.168]. These results illustrate that lunchtime physical demands do not affect tinnitus severity.

*Evening Physical demands*

Table 57

*Means and standard deviations for evening tinnitus severity as determined by physical demand (n = 24)*

| | Physical demands (evening) | | | | | |
|---|---|---|---|---|---|---|
| | Means | | | Standard Deviations | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (evening)** | 2.97 | 3.08 | 2.77 | .437 | .151 | .590 |

A univariate ANOVA saw the use of evening physical demand as the independent variable and tinnitus severity as the dependent variable. There was no significant effect of such demands on tinnitus awareness [$F$ (2, 21) = 1.033; $p$ = 0.373; partial eta squared = 0.090].

*Overall Physical demands*

Table 58

*Overall tinnitus severity, categorised by physical demands*

| | Overall Physical demands | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Overall Tinnitus Severity** | 2.98 | 3.06 | 2.90 | .387 | .133 | .398 |

The univariate ANOVA investigating the effects of overall physical demands on judgement of tinnitus severity during the course of the day required the use of overall physical demands - a collapsed average - as the independent variable and overall tinnitus severity as the dependent variable. This showed that there was no significant effect of physical demand on tinnitus awareness [$F$ (2, 21) = 0.486; $p$ = 0.622; partial eta squared = 0.044]. In summary, it would appear that physical demands - whatever the time of day - have no effect on tinnitus severity.

In conclusion, the splitting up of the combined demand measures into their three component parts has resulted in the discovery that both emotional and physical demands play no part in the process. It is a different story for mental demand - specifically the enduring effects of morning mental demand on tinnitus severity (Figure 14, page 184) and the more immediate main effect of evening mental demand (Figure 15 page 187). Thus, specific levels of mental demand during the day would seem to affect tinnitus severity towards the end of that day. Lower levels of demand result in lower reported tinnitus severity. As demand increases from low to moderate/high levels, subjective tinnitus severity increases also.

*The State Demand Hypothesis (Concentration, Effort, Time Pressure)*

In addition, other demand-related variables were sought; namely effort demanded, concentration required, and sense of time pressure variables that referred to what was happening to the participant in the fifteen minutes immediately prior to the completion of that part of the daily diary. This allows for investigation of short-term and long-term impact of short periods of demand, allowing for closer comparison with the laboratory studies. Distinct to the more general demand variables, these three specifically measured the same short period of time as the tinnitus items (i.e. the previous fifteen minutes), and not a perception of that time of day in general. As such, further ANOVAs were run utilising the same principles as those ascribed to above, investigating what effect such demands have on reported tinnitus severity.

*The State Demand Hypothesis (Concentration)*

*Morning Concentration required - "last fifteen minutes"*

Table 59

*Means tinnitus severity, categorised by reported concentration (n = 24)*

| | **Concentration required in last 15 minutes (morning)** | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (morning)** | 2.80 | 3.10 | 3.07 | .360 | .187 | .233 |
| **Tinnitus level (lunchtime)** | 2.95 | 2.98 | 2.91 | .341 | .240 | .167 |
| **Tinnitus level (evening)** | 3.07 | 2.95 | 2.79 | .354 | .315 | .588 |

Investigating the effect of concentration demanded (morning) required a 3x3 mixed ANOVA, with concentration as the independent variable and three separate measurements of tinnitus severity as the repeated measure for time of day. There was no main effect of concentration [$F$ (2, 21) = 0.190; $p$ = 0.828 ns.; partial eta squared = 0.018]. Investigation of time of day saw a significant result for Mauchley's Test of Sphericity, requiring Greenhouse-Geisser epsilon values [$F$ (1.223, 25.883) = 0.467; $p$ = 0.630 ns.; partial eta squared = 0.022]. Nevertheless, there was a highly significant interaction [$F$ (4, 42) = 4.230; $p$ = 0.006; partial eta squared = 0.287] between concentration levels and time of day.

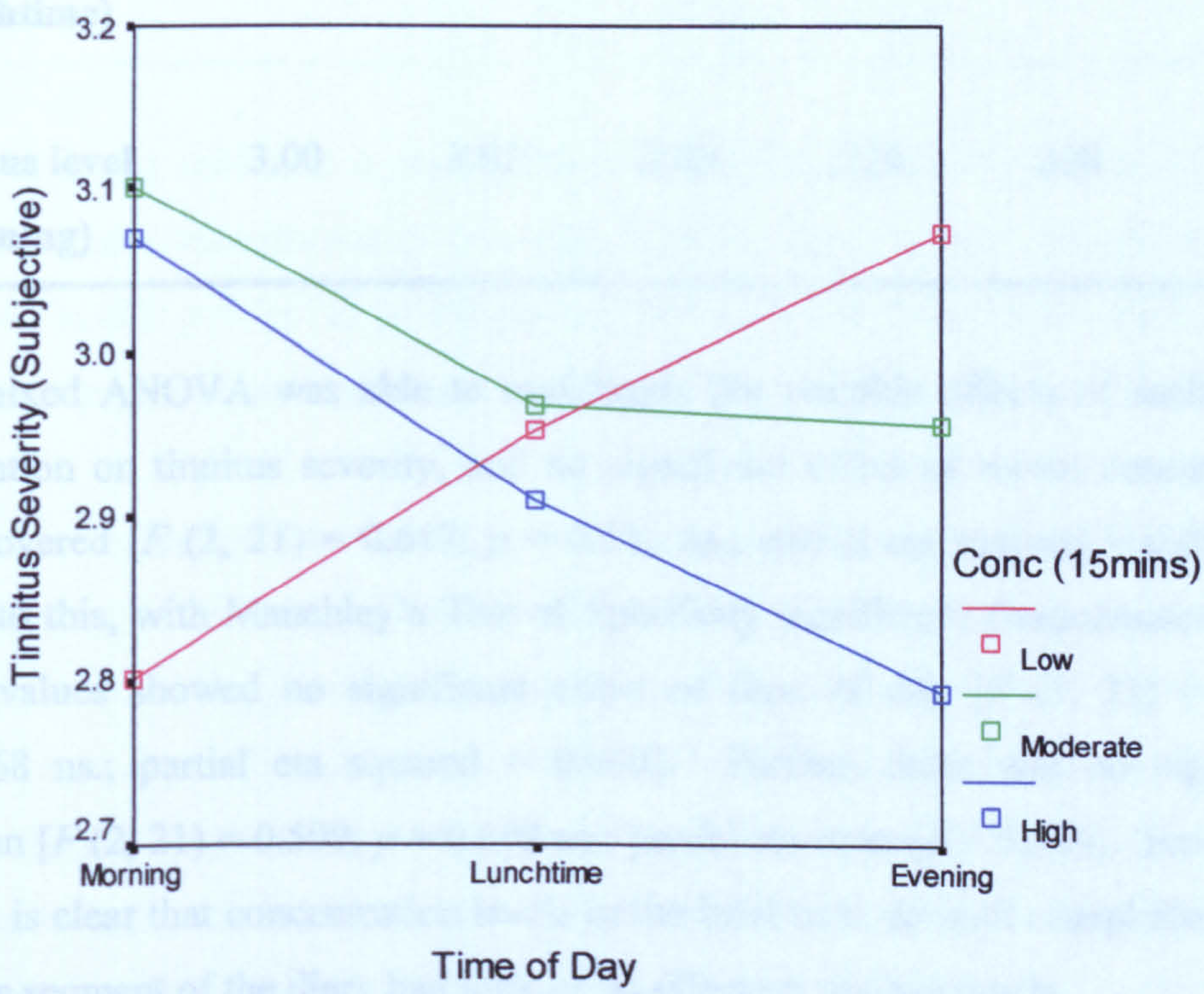



Figure 16: Interaction between concentration demanded (morning) and reported tinnitus severity.

This interaction serves to illustrate the difference between those reporting low levels of concentration and those that reporting moderate/high levels of concentration. Higher levels of morning concentration lead to reduced tinnitus levels later in the day, but more importantly, the reverse is also true. Lower morning concentration levels clearly impact on tinnitus severity later in the day.

*Lunchtime Concentration required - "last fifteen minutes"*

Table 60

Mean tinnitus severity with regards to lunchtime concentration *(n = 24)*

| | Concentration required in last 15 minutes (lunchtime) | | | | | |
|---|---|---|---|---|---|---|
| | Means | | | Standard Deviations | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (lunchtime)** | 2.98 | 2.96 | 2.88 | .257 | .224 | .285 |
| **Tinnitus level (evening)** | 3.00 | 3.02 | 2.80 | .224 | .308 | .657 |

A 3x2 mixed ANOVA was able to investigate the possible effects of such recent concentration on tinnitus severity, and no significant effect of recent concentration was discovered [$F$ (2, 21) = 0.617; $p$ = 0.541 ns.; partial eta squared = 0.057]. In addition to this, with Mauchley's Test of Sphericity significant, Greenhouse-Geisser epsilion values showed no significant effect of time of day [$F$ (1, 21) = 0.002; $p$ = 0.968 ns.; partial eta squared = 0.000]. Further, there was no significant interaction [$F$ (2, 21) = 0.509; $p$ = 0.608 ns.; partial eta squared = 0.046]. From these results, it is clear that concentration levels in the brief time up until completion of the lunchtime segment of the diary had little or no effect on tinnitus levels.

*Evening Concentration required - "last fifteen minutes"*

Table 61

*Evening tinnitus descriptives, as defined by concentration (n = 24)*

| | Concentration required in last 15 minutes (evening) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (evening)** | 3.02 | 2.82 | 2.99 | .234 | .232 | .695 |

With no repeated measure, a straightforward univariate ANOVA investigated the effects of recent concentration on evening tinnitus. There was no significant effect [$F$ (1, 21) = 0.400; $p$ = 0.676; partial eta squared = 0.037], and so it is concluded that no relationship exists between the two.

Unlike the other demand variables, it is not as straightforward to collapse together these "fifteen minute" ones. Conceptually, each is a precise measure of a specific point in time and unlike the others, can not be readily generalised to the rest of the day. As such, it was decided not to pursue an overall relationship with tinnitus for any of the three, namely: concentration required; effort demanded; or time pressure felt. So in conclusion, a significant interaction is apparent between tinnitus severity and levels of concentration demand immediately before completion of the morning third of the diary (Figure 16, page 194) and this would also seem to be of importance later in the day and as such, there is partial support for the hypothesis.

*The State Demand Hypothesis (Effort)*

*Morning Effort demanded - "last fifteen minutes"*

Table 62

*Descriptives for tinnitus severity, as determined by morning effort (n = 24)*

| | Effort demanded in last 15 minutes (morning) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (morning)** | 2.79 | 3.12 | 3.06 | .351 | .213 | .209 |
| **Tinnitus level (lunchtime)** | 2.86 | 3.07 | 2.89 | .284 | .237 | .197 |
| **Tinnitus level (evening)** | 2.96 | 3.13 | 2.73 | .253 | .295 | .606 |

This 3x3 mixed ANOVA found no significant main effect of recent effort (morning) [$F$ (2, 21) = 1.870; $p$ = 0.179 ns.; partial eta squared = 0.151], and there was no significant effect of time of day on severity [F (2, 42) = 0.434; p = 0.651 ns.; partial eta squared = 0.020] though a significant interaction did exist between effort and time of day [$F$ (4, 42) = 3.185; $p$ = 0.023; partial eta squared = 0.233].

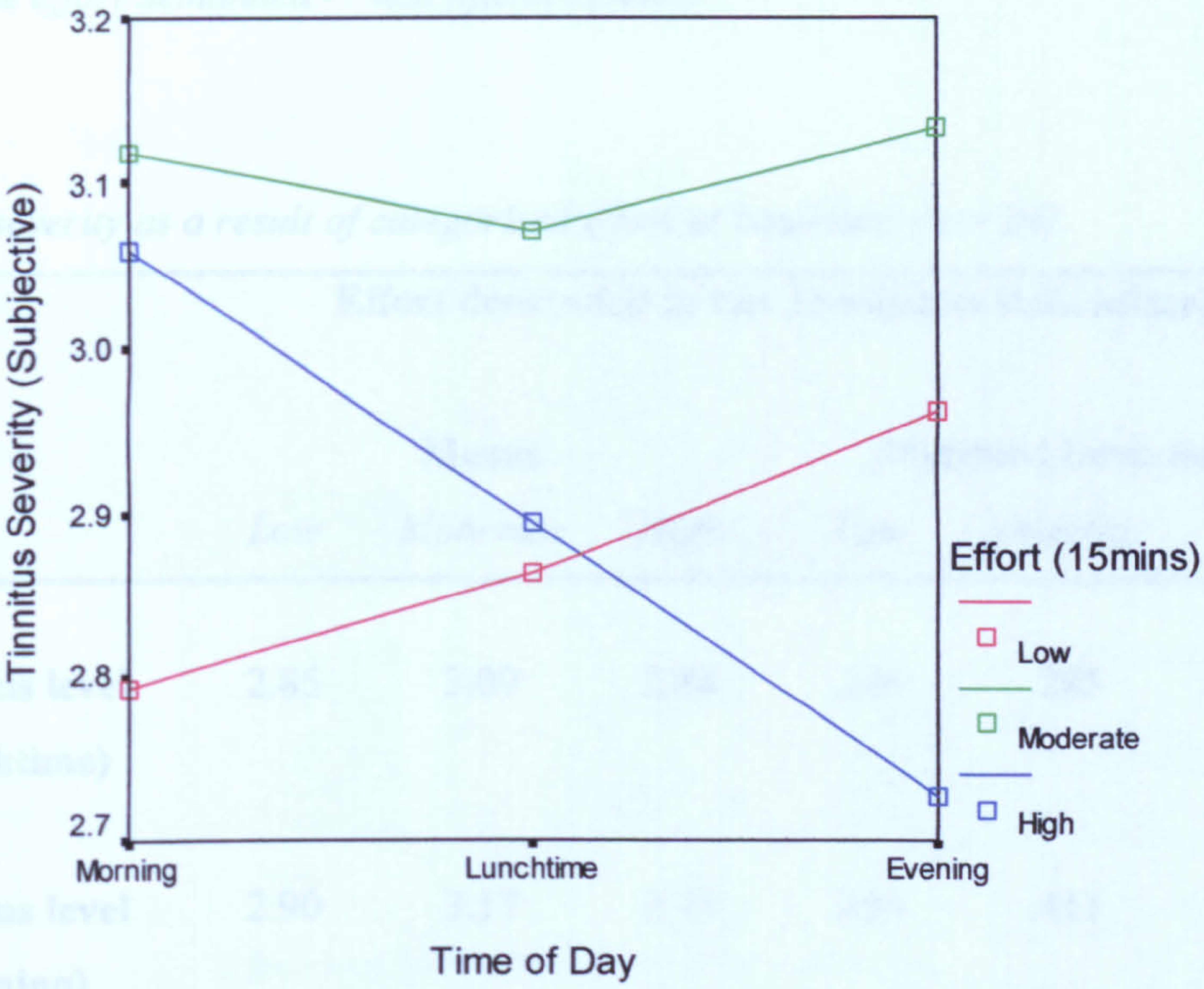



Figure 17: Relationship between effort demanded (morning) and subjective tinnitus severity during the day.

On average, those individuals reporting a need to make either the most/least amount of effort also reported similar overall tinnitus ratings during the course of the day. Figure 17 illustrates that the interaction lies in the disordinal relationship between low and high effort as distinct from the greater consistency of those needing to put in more moderate amounts. It suggests that moderate and high effort results in higher levels of tinnitus in the morning, yet as the day progresses, those tinnitus sufferers reporting the highest levels of effort also reported the lowest awareness of their tinnitus in the evening. It is also noteworthy that the disordinal interaction is a similar pattern to that of morning concentration (Figure 16, page 194).

*Lunchtime effort demanded - "last fifteen minutes"*

Table 63

*Tinnitus severity as a result of categorised effort at lunchtime (n = 24)*

| | Effort demanded in last 15 minutes (lunchtime) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (lunchtime)** | 2.85 | 3.09 | 2.88 | .246 | .285 | .147 |
| **Tinnitus level (evening)** | 2.90 | 3.17 | 2.74 | .180 | .411 | .548 |

The 3x2 mixed ANOVA found that while there was no main effect of such effort on perception of the tinnitus sensation, there was a tendency towards significance and a large effect size* [$F$ (2, 21) = 2.742; $p$ = 0.088 ns.; partial eta squared = 0.207]. There was no significant main effect of time of day [$F$ (1, 21) = 0.002; $p$ = 0.967 ns.; partial eta squared = 0.000] and no interaction between the measures [$F$ (2, 21) = 1.170; $p$ = 0.392 ns.; partial eta squared = 0.100].

*Although there was no significant main effect of recent effort, the nature of diary studies and the sizable partial eta squared value ($\eta_p^2 = 0.207$) suggested that use of a post hoc test may be of benefit. For this reason, a post hoc test was undertaken.

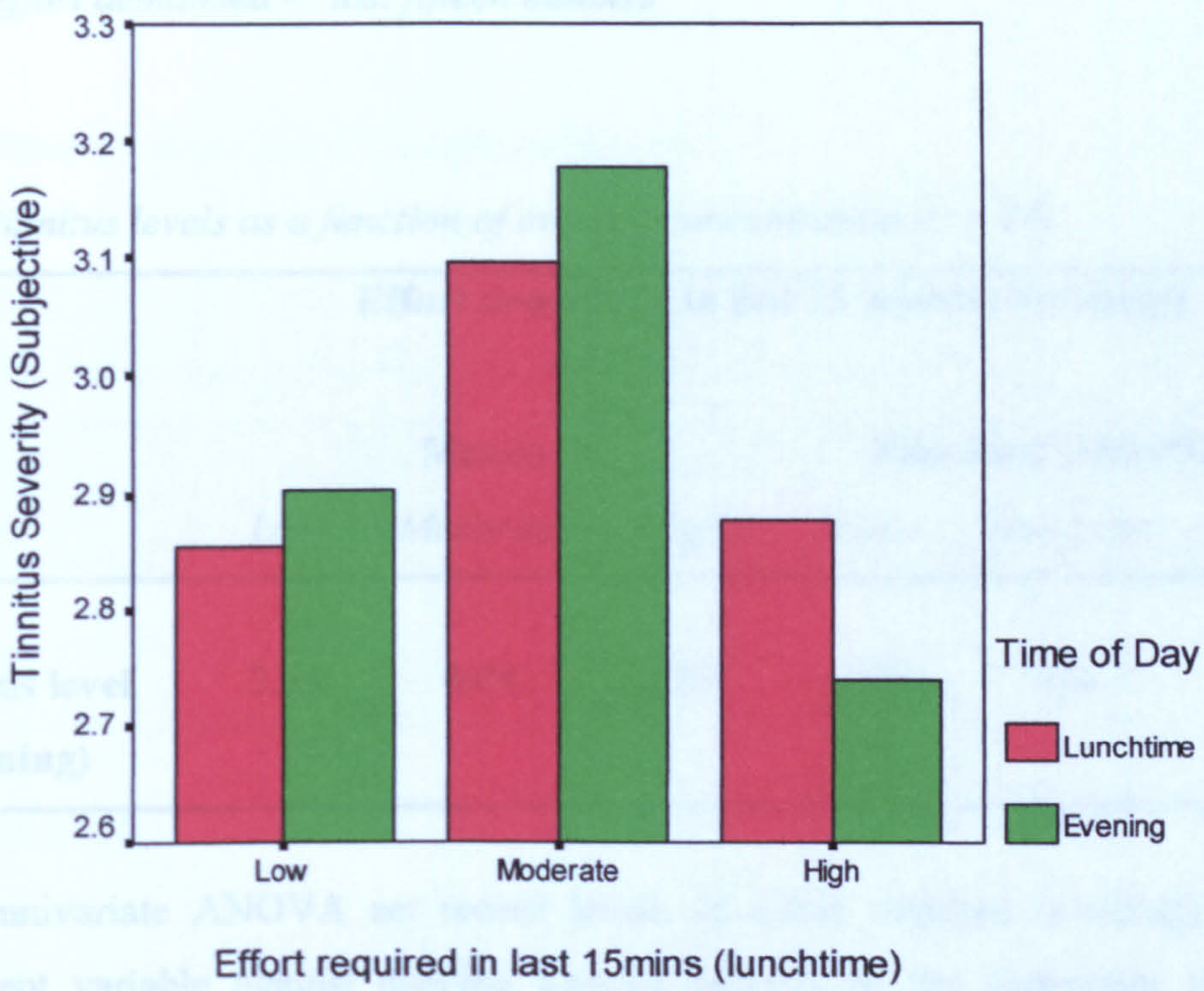



Figure 18: Reported tinnitus as a function of recent effort (lunchtime) and time of day.

This depicts the findings of the LSD test, namely a significant overall difference between moderate and high effort ($p = 0.037$) and a tendency towards significance between moderate and low effort ($p = 0.097$ ns.), though there was no difference to be found between the two extremes ($p = 0.640$ ns.). From this, there is some evidence to suggest that participants reporting moderate levels of effort in the last fifteen minutes before lunchtime are encountering, and so reporting, more severe tinnitus than their counterparts. This is very much similar to the earlier concentration/effort interactions, and indicative of a moderating effect of demand on tinnitus.

*Evening effort demanded - "last fifteen minutes"*

Table 64

*Evening tinnitus levels as a function of evening concentration (n = 24)*

| | Effort demanded in last 15 minutes (evening) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (evening)** | 2.95 | 3.04 | 2.83 | .225 | .436 | .591 |

Here, a univariate ANOVA set recent levels of effort required (evening) as the independent variable against evening tinnitus severity as the dependent variable. From this, it was apparent that there was no difference in tinnitus severity due to the effort demanded of the participants immediately beforehand [$F$ (2, 21) = 0.434; $p$ = 0.654 ns.; partial eta squared = 0.040]. As such, possible effects of evening effort on tinnitus severity levels must be discounted.

As a variable, "effort demanded in the last fifteen minutes" would seem to affect individual perceptions of tinnitus. For one ANOVA, there was a clear and strong interaction between morning effort levels and time of day (Figure 17, page 198). This is echoed by the main effect of effort at lunchtime (Figure 18, page 200) which also insinuates that moderate levels of effort go hand in hand with more severe tinnitus. There is no effect in the evening, but this may be partially explained away by the fact that any consequences are easier to spot later on (i.e. effects of evening demand may be seen the following morning or through affected sleep patterns), and this suggests the possibility of a delay in effect.

*The State Demand Hypothesis (Time Pressure)*

*Morning Time Pressure felt - "last fifteen minutes"*

Table 65

*Tinnitus severity scores, categorised by time pressure in the morning (n = 24)*

| | Time Pressure felt in last 15 minutes (morning) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (morning)** | 2.88 | 3.07 | 3.04 | .384 | .222 | .222 |
| **Tinnitus level (lunchtime)** | 2.93 | 2.94 | 2.97 | .292 | .241 | .236 |
| **Tinnitus level (evening)** | 2.93 | 3.07 | 2.83 | .222 | .361 | .645 |

The 3x3 mixed ANOVA saw time pressure perceived by the participant as the independent variable. As ever, the repeated measure was the time of day in which tinnitus severity was reported. There turned out to be no effect of recent time pressure on tinnitus severity [$F$ (2, 21) = 0.324; p = 0.742 ns.; partial eta squared = 0.028]. Due to a significant value for Mauchley's Test of Sphericity, Greenhouse-Geisser epsilon values showed no main effect of time of day [$F$ (1.241, 26.055) = 0.439; $p$ = 0.555 ns.; partial eta squared = 0.020]. In addition to this, there was no interaction [$F$ (4, 42) = 1.116; p = 0.362 ns.; partial eta squared = 0.096]. As such, the idea of perceived time pressure (morning) affecting subjective tinnitus severity can be rejected.

*Lunchtime Time Pressure felt - "last fifteen minutes"*

Table 66

*Tinnitus severity from early afternoon onwards, as determined by lunchtime time pressure (n = 24)*

| | Time Pressure felt in last 15 minutes (lunchtime) | | | | | |
|---|---|---|---|---|---|---|
| | Means | | | Standard Deviations | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (lunchtime)** | 2.94 | 2.93 | 2.96 | .296 | .240 | .240 |
| **Tinnitus level (evening)** | 2.96 | 2.99 | 2.87 | .234 | .373 | .641 |

This 3x2 mixed ANOVA found no significant main effect of recent time pressure [$F$ (2, 21) = 0.039; $p$ = 0962 ns; partial eta squared = 0.04], no effect of time of day [$F$ (1, 21) = 0.002, $p$ = 0.968 ns.; partial eta squared = 0.000] and no significant interaction [$F$ (2, 21) = 0.482; $p$ = 0.624 ns.; partial eta squared = 0.044]. From these results, it can be safely concluded that sense of time pressure apparent at lunchtime has no effect on perception of tinnitus severity.

*Evening Time Pressure felt - "last fifteen minutes"*

Table 67

*Evening tinnitus levels as a function of recent time pressure (n = 24)*

| | Time Pressure felt in last 15 minutes (evening) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Tinnitus level (evening)** | 2.90 | 3.02 | 2.90 | .164 | .329 | .684 |

A univariate ANOVA concluded that there was no main effect of time pressure on tinnitus severity [$F$ (1, 21) = 0.180; $p$ = 0.836 ns.; partial eta squared = 0.017]. Therefore, sense of encroaching time pressure did not and does not affect tinnitus severity. Taken alongside the lack of significant findings for any aspect of time pressure and it can be firmly concluded that a sense of time pressure is not a significant factor in tinnitus generation/awareness.

*Summary (The Demand & State Demand Hypotheses)*

As has been seen, a number of mixed ANOVAs were run on the various demand hypotheses: whether overall demand; component parts of the combined variable; or the ratings given in describing the fifteen previous minutes. For this reason, it is best to restate the significant - and thus, relevant - results of these ANOVAs.

Table 68

*Summary of significant Demand hypothesis ANOVAs (n=24)*

| ***Significant results (Demand Hypothesis)*** | ***Probability*** |
|---|---|
| Interaction between overall demand (lunchtime) and time of day (page 175). | Tendency ($p = 0.066$ ns.). |
| Main effect of evening demand (page 177). | Tendency ($p = 0.085$ ns.). |
| Interaction between mental demands (morning) and time of day (page 183). | $p = 0.012$. |
| Main effect of evening mental demand (page 186). | $p = 0.007$. |

These significant and near-significant results highlight a number of points. Firstly, that in general, lunchtime demand levels help to determine evening tinnitus levels, with more moderate levels of demand resulting in the worst tinnitus. Secondly, a suggestion that moderate evening demand may result in the most severe tinnitus. However, this same tendency (Table 45, page 177) also shows the highest levels of demand resulting in the lowest subjective tinnitus severity. Finally, that both morning and evening mental demands will affect tinnitus at the end of the day (evening), with the lowest levels of demand resulting in reduced tinnitus awareness.

Table 69

*Summary of significant State Demand Hypothesis ANOVAs (n = 24)*

| ***Significant results*** ***("last fifteen minutes" Demand Hypothesis)*** | ***Probability*** |
|---|---|
| Interaction between concentration demanded in morning and time of day (page 194). | $p = 0.006$. |
| Interaction between effort demanded in morning and time of day (page 197). | $p = 0.023$ |
| Main effect of lunchtime effort demanded (page 199). | Tendency ($p = 0.088$ ns.). |

The interaction between morning concentration levels and time of day show that tinnitus sufferers concentrating less, appear to report increasingly severe tinnitus as the day goes on - as opposed to the gradual drop in those individuals reporting high concentration levels. In addition, a similar result was found for effort demanded of the individual in the morning - albeit a more muted one. Low/high levels of effort have different effects to moderate levels, with individuals facing the latter being separate and more consistent in their reported tinnitus awareness. This concept is further supported by the near-significant main effect of lunchtime effort (page 199), which showed significant and near-significant post hoc differences between moderate and low/high levels of effort demanded both at that moment - lunchtime - and into the evening.

What these results show is that certain types of demand can moderate tinnitus severity, both at that moment, and as a consequence of those demands later in the day. Yet, most importantly, there is some confusion in the direction that this relationship takes. High demand does not necessarily translate into greater tinnitus perception (Table 45, page 177).

*The Performance Hypothesis (self-reported effectiveness)*

Study Two provided the rationale for the hypothesis that cognitive demand moderates tinnitus severity. It also showed performance decrements in tinnitus sufferers under certain conditions, resulting in increased severity/awareness. Since the performance hypothesis states that individual performance may be a factor determining tinnitus awareness, it was decided to correlate tinnitus severity with personal performance. This allows for the added advantage of being able to partial out scores on the STSS for a clearer picture of possible relationships.

Table 70

*Correlation matrix between tinnitus severity and personal effectiveness - subjective tinnitus severity score partialled out (n = 24)*

| Variables | Tinnitus (morning) | Tinnitus (lunch) | Tinnitus (evening) | EFFECT (morning) | EFFECT (lunch) |
|---|---|---|---|---|---|
| **Tinnitus (lunchtime)** | .819** | | | | |
| **Tinnitus (evening)** | .430* | .617** | | | |
| **Effectiveness (morning)** | .257 | .385 | .147 | | |
| **Effectiveness (lunchtime)** | -.510* | .133 | .380 | .762** | |
| **Effectiveness (evening)** | -.058 | .102 | -.001 | .690** | .940** |

* $p < 0.05$; ** $p < 0.01$.

Unsurprisingly, both the subjective tinnitus variables and the effectiveness variables correlate well with themselves. There is no visible linear relationship between the two - besides the moderate correlation between morning tinnitus severity and lunchtime performance. Nevertheless, this is proof of tinnitus impacting negatively on later performance, and further support of a delayed effect.

*Moderation Hypothesis (Demand and Performance in Tinnitus Sufferers)*

The ANOVAs above show limited effects of demand on tinnitus severity, some of these being in interaction with time of day. However, the laboratory studies indicated a possible relationship between demand and performance for tinnitus sufferers. Since all diary participants were tinnitus sufferers, it is also appropriate to simply investigate changes in performance over increasing demands without the need to consider the tinnitus sensation itself.

Table 71

*Personal effectiveness during day as a function of overall demand (n = 24)*

| | Overall Demand | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Effectiveness (morning)** | 6.33 | 4.99 | 6.90 | 1.026 | .825 | 1.431 |
| **Effectiveness (lunchtime)** | 6.45 | 5.29 | 6.67 | .962 | .981 | 1.76 |
| **Effectiveness (evening)** | 6.48 | 5.44 | 6.57 | .965 | 1.393 | 1.619 |

Investigation into this particular relationship needed a 3x3 mixed ANOVA. It provided evidence of a significant main effect of demand [$F$ (2, 21) = 3.577; $p$ = 0.046; partial eta squared = 0.254]. However, there was no effect of time of day [$F$ (1, 21) = 0.224; $p$ = 0.641 ns.; partial eta squared = 0.011], and no interaction present [$F$ (2, 21) = 1.488; $p$ = 0.249 ns.; partial eta squared = 0.124]. Due to the three levels that made up the demand variable, a post hoc test was required to accurately ascertain where the difference lay. The LSD test was utilised.

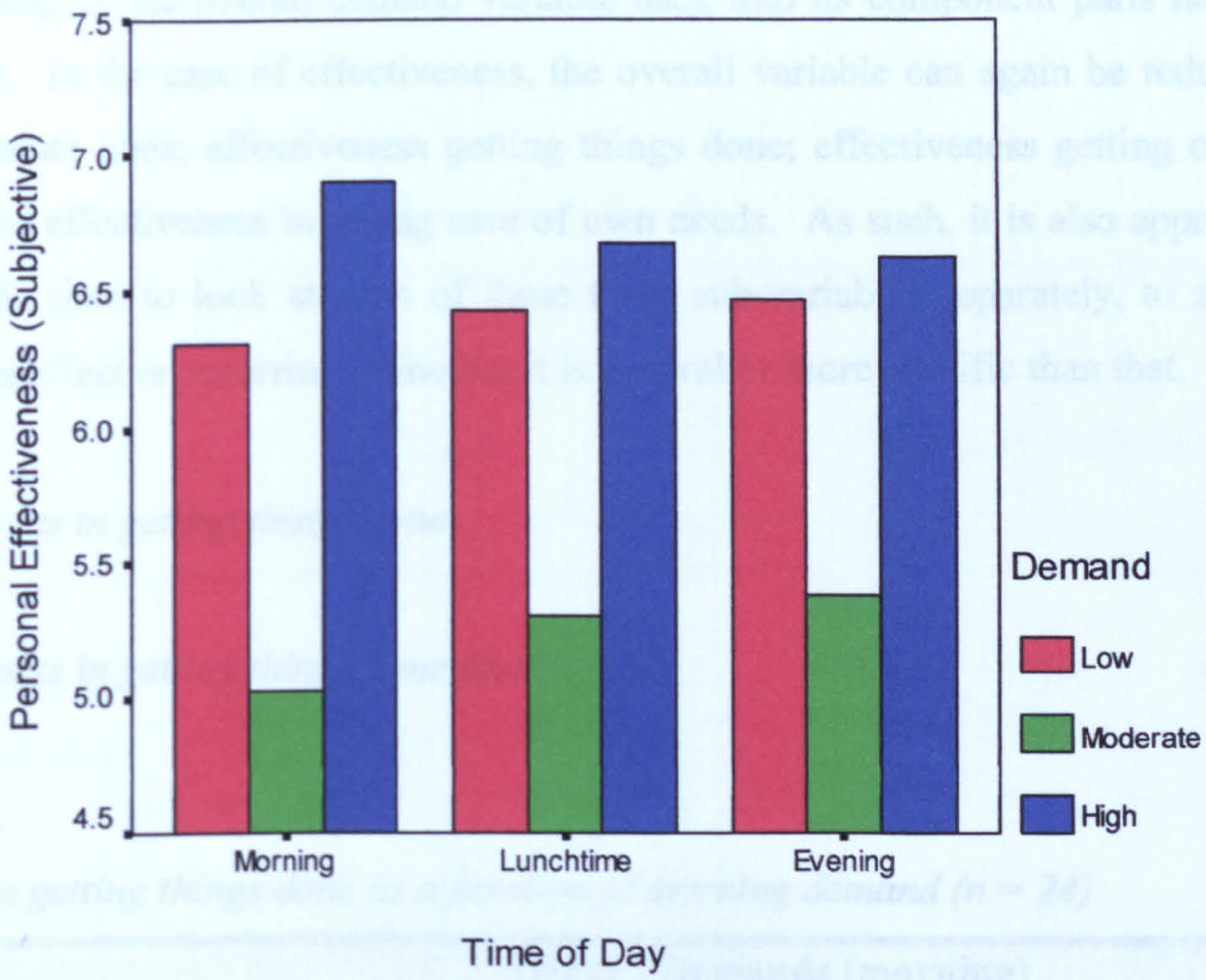



Figure 19: Illustration of the descriptive data found in Table 71 (page 208).

As is shown, participants reporting moderate demand also report much reduced personal effectiveness (performance). This is supported by the post hoc which shows significant differences between moderate and high demands ($p$ = 0.020) and a near significant difference between moderate and low demands ($p$ = 0.056 ns.). The self-reported performance for low and high demands are comparable ($p$ = 0.620 ns.). In some ways, this contravenes the expected result in that Study One - and Study Two especially - suggest moderate demands are linked to both reduced awareness of tinnitus severity and a comparable performance to controls. Yet, while the above goes against this, it still shows a significant difference between tinnitus sufferers facing low/high demands compared to those undergoing moderate demands. Therefore, the spirit of the hypothesis can justifiably be maintained and will be discussed in greater detail below.

The splitting of the overall demand variable back into its component parts has set a precedent. In the case of effectiveness, the overall variable can again be reduced to three separate ones; effectiveness getting things done; effectiveness getting on with others; and effectiveness in taking care of own needs. As such, it is also appropriate to take the time to look at each of these three sub-variables separately, to see just where this effect is occurring - whether it is general or more specific than that.

*Effectiveness in getting things done*

*Effectiveness in getting things done (morning)*

Table 72:

*Success in getting things done as a function of morning demand (n = 24)*

| | **Overall Demands (morning)** | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Getting things done (morning)** | 6.15 | 6.39 | 6.07 | 1.287 | 1.552 | 1.579 |
| **Getting things done (lunchtime)** | 6.40 | 6.06 | 6.31 | 1.145 | 1.903 | 1.349 |
| **Getting things done (evening)** | 6.56 | 5.91 | 6.17 | 1.307 | 1.940 | 1.563 |

To investigate effects of morning demands on "getting things done", a 3x3 mixed ANOVA used level of demand the independent measure and time of day as the repeated measure. This showed no effect of demand [$F$ (2, 21) = 0.63; $p$ = 0.939 ns.; partial eta squared = 0.006], no effect of time of day [$F$ (2, 42) = 0.64; $p$ = 0.938 ns.; partial eta squared = 0.003], and no interaction [$F$ (4, 21) = 1.279; $p$ = 0.294 ns.; partial eta squared = 0.109].

*Effectiveness in getting things done (lunchtime)*

Table 73

*Lunchtime perception of getting things done (n = 24)*

| | Overall Demands (lunchtime) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Getting things done (lunchtime)** | 6.65 | 5.44 | 6.72 | 1.191 | 1.066 | 1.680 |
| **Getting things done (evening)** | 6.50 | 5.59 | 6.57 | 1.129 | 1.486 | 1.778 |

The 3x2 mixed ANOVA found no main effect of demand [$F$ (2, 21) = 1.632; $p$ = 0.219 ns.; partial eta squared = 0.135], no difference evident due to time of day [$F$ (1, 21) = 0.265; $p$ = 0.612 ns.; partial eta squared = 0.012], and no interaction between the two of them [$F$ (2, 21) = 1.160; $p$ = 0.333 ns.; partial eta squared = 0.100].

*Effectiveness in getting things done (evening)*

Table 74

*Evening perception of getting things done, as function of demand (n = 24)*

| | Overall Demands (evening) | | | | | |
|---|---|---|---|---|---|---|
| | Means | | | Standard Deviations | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Getting things done (evening)** | 6.62 | 6.02 | 6.10 | 1.116 | 1.332 | 1.976 |

Again, as before, no repeated measure is possible when considering happenings in the evening portion of the diary study. A univariate ANOVA is again appropriate, with evening demands as the independent variable against the dependent variable of effectiveness in getting things done (evening). No visible effect of evening demand was seen [$F$ (2, 21) = 0.335; $p$ = 0.719 ns.; partial eta squared = 0.031]. This finding is consistent with the above, and thus any consequence of demand on individual perception of "getting things done" - i.e. sense of personal performance - must be discounted for tinnitus sufferers. As ever, this does not mean that there is no effect of demand on performance, only that one is not perceived by the sufferer.

*Effectiveness in getting on well with others*

*Effectiveness in getting on well with others (morning)*

Table 75

*Getting on well with others, as a function of morning demand (n = 24)*

| | Overall Demands (morning) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Getting on with others (morning)** | 6.25 | 6.19 | 5.46 | 1.224 | 2.179 | 1.843 |
| **Getting on with others (lunch)** | 6.28 | 6.14 | 5.82 | 1.126 | 1.983 | 1.832 |
| **Getting on with others (evening)** | 6.85 | 5.46 | 5.69 | 1.030 | 2.078 | 1.941 |

Investigating this particular relationship required 3x3 mixed ANOVA. There was no main effect of demand on this effectiveness variable [$F$ (2, 21) = 0.552; $p$ = 0.584 ns.; partial eta squared = 0.050]. No significant main effect of time of day was found [$F$ (2, 42) = 0.102; $p$ = 0.904 ns.; partial eta squared = 0.005] and further, there was no interaction [$F$ (4, 42) = 1.443; $p$ = 0.237 ns.; partial eta squared = 0.121]. Thus, morning demand does not effect the personal perception that tinnitus sufferers have of their success in dealing with other people.

*Effectiveness in getting on well with others (lunchtime)*

Table 76

*Personal effectiveness in terms of lunchtime demand faced (n = 24)*

| | Overall Demands (lunchtime) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Getting on with others (lunch)** | 6.47 | 4.99 | 6.74 | 1.218 | 1.167 | 2.011 |
| **Getting on with others (evening)** | 6.89 | 5.18 | 5.96 | .9876 | 1.608 | 2.098 |

A 3x2 mixed ANOVA reported on possible effects of lunchtime demand levels on self-rated ability to get on well with others. It found no main effect of demand [$F$ (2, 21) = 2.476; $p$ = 0.108 ns.; partial eta squared = 0.191], nor an effect of time of day [$F$ (1, 21) = 0.104; $p$ = 0.750 ns.; partial eta squared = 0.005], but it did uncover a significant interaction between the two measures [$F$ (2, 21) = 4.402; $p$ = 0.025; partial eta squared = 0.295].

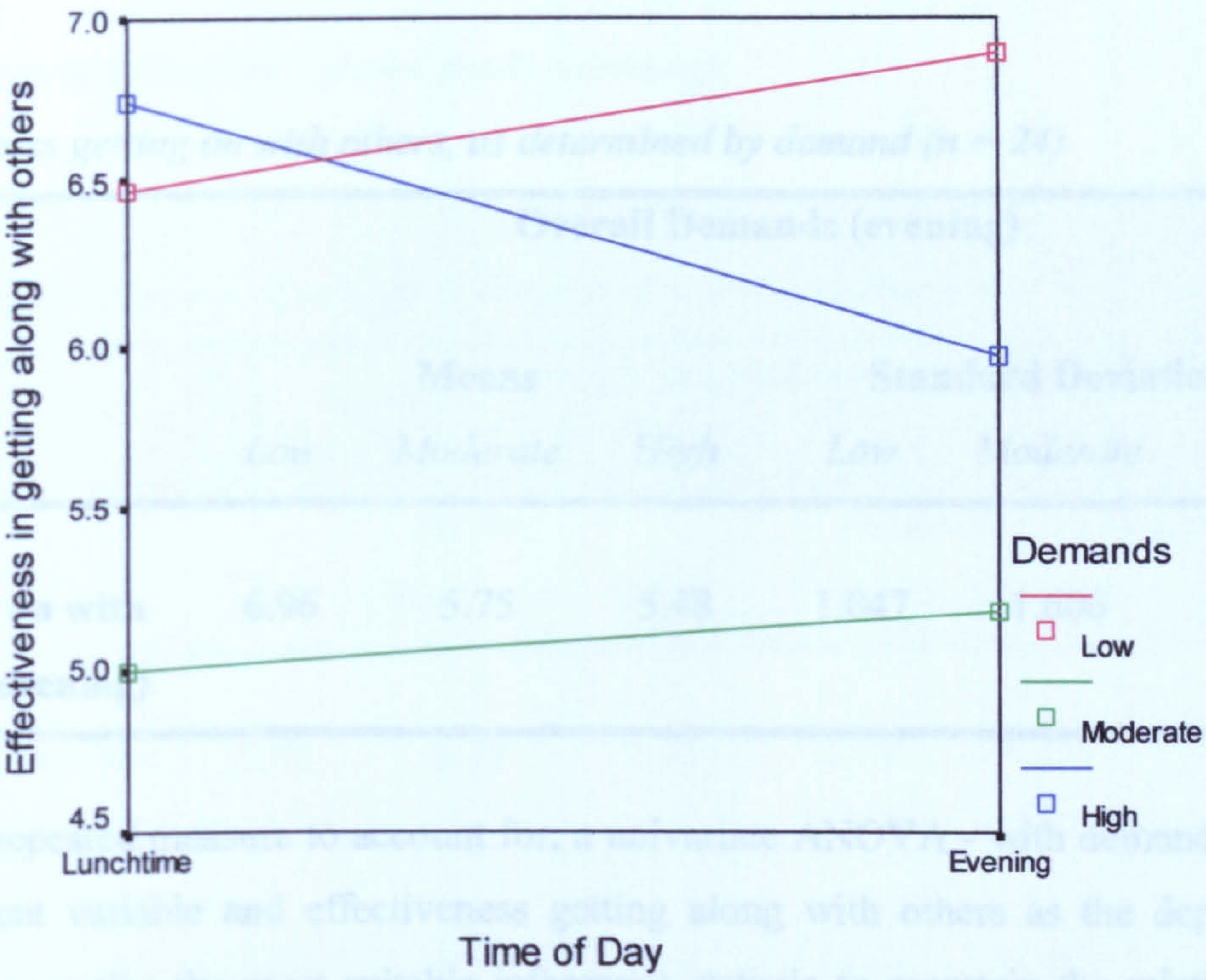



Figure 20: Significant interaction between time of day and lunchtime demand.

Here, the interaction is clearly due to the poor self-effectiveness in getting along with others that is perceived by the participants facing moderate demands. Again, tinnitus sufferers facing moderate levels of demand look distinct to their contemporaries - though this difference is not significant. Further support can be drawn from the fact that while there was no significant effect of demand, there was a high value for partial eta squared ($\eta_p^2 = 0.191$), suggesting a difference between low/high and moderate demands in terms of perception of "getting along with others". Instead, the interaction must come from the decreasing sense of personal effectiveness in tinnitus sufferers facing high levels of lunchtime demand, whereas in those facing low demands, personal sense of performance increases. The slump in this value for those high demand individuals is no doubt the reason for an interaction and not a main effect. This suggests tinnitus suffers suffering high demands will do worse when interacting with people later on, or at the very least that they perceive this to be the case. This may be due to a number of reasons, but the one that most readily springs to mind is the sense of irritation that accompanies more severe tinnitus - which may have been promoted through the cost of dealing with higher demands earlier on in the day.

*Effectiveness in getting on well with others (evening)*

Table 77

*Effectiveness getting on with others, as determined by demand (n = 24)*

| | Overall Demands (evening) | | | | | |
|---|---|---|---|---|---|---|
| | | **Means** | | | **Standard Deviations** | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Getting on with others (evening)** | 6.96 | 5.75 | 5.48 | 1.047 | 1.606 | 2.108 |

With no repeated measure to account for, a univariate ANOVA - with demand as the independent variable and effectiveness getting along with others as the dependent variable - remains the most suitable inferential statistic to ascertain the relationship between them. It showed no main effect of demand [$F$ (2, 21) = 1.652; $p$ = 0.216 ns.; partial eta squared = 0.136].

Yet, unlike effectiveness in getting things done, effectiveness in getting along with others does seem to be affected by levels of demand (lunchtime) and so these findings will be expanded on in the discussion.

*Effectiveness in taking care of own needs*

*Effectiveness in taking care of own needs (morning)*

Table 78

*Success in taking care of needs, as a function of morning demand (n = 24)*

| | **Overall Demands (morning)** | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Taking care of needs (morning)** | 5.79 | 6.35 | 6.26 | 1.030 | 1.511 | 1.395 |
| **Taking care of needs (lunchtime)** | 5.86 | 5.95 | 6.31 | 1.152 | 1.796 | 1.268 |
| **Taking care of needs (evening)** | 6.03 | 6.01 | 6.29 | 1.090 | 1.761 | 1.459 |

The 3x3 mixed ANOVA found that there no main effect of demand [$F$ (2, 21) = 0.193; $p$ = 0.826 ns.; partial eta squared = 0.018]. In addition, with Greenhouse-Geisser epsilon values quoted here due a significant result for Mauchley's Test of Sphericity, there was no main effect of time of day [$F$ (1.242, 26.084) = 0.161; $p$ = 0.852 ns.; partial eta squared = 0.008]. Furthermore, there was no interaction [$F$ (4, 42) = 0.610; $p$ = 0.657 ns.; partial eta squared = 0.055].

*Effectiveness in taking care of own needs (lunchtime)*

Table 79

*Taking care of own needs, as moderated by lunchtime demand (n = 24)*

| | Overall Demands (lunchtime) | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Taking care of needs (lunchtime)** | 6.18 | 5.44 | 6.56 | 1.251 | 1.023 | 1.648 |
| **Taking care of needs (evening)** | 6.13 | 5.62 | 6.62 | 1.044 | 1.360 | 1.680 |

The 3x2 mixed ANOVA saw no significant effect of demand [$F$ (2, 21) = 1.261; $p$ = 0.304 ns.; partial eta squared = 0.107], no effect of time of day [$F$ (1, 21) = 0.578; $p$ = 0.456 ns.; partial eta squared = 0.027] and no interaction [$F$ (2, 21) = 0.578; $p$ = 0.570 ns.; partial eta squared = 0.052]; indicating lunchtime demand and effectiveness in taking care of personal needs are unrelated.

*Effectiveness in taking care of own needs (evening)*

Table 80

*Taking care of needs, as function of overall evening demand (n = 24)*

| | **Overall Demands (evening)** | | | | | |
|---|---|---|---|---|---|---|
| | **Means** | | | **Standard Deviations** | | |
| | *Low* | *Moderate* | *High* | *Low* | *Moderate* | *High* |
| **Taking care of needs (evening)** | 6.25 | 6.05 | 6.10 | 1.072 | 1.286 | 1.854 |

The final ANOVA of this section is univariate due to the lack of an appropriate repeated measure. Evening demand was the independent variable and evening personal effectiveness in dealing with own needs was the dependent variable. It produced no visible effect of demand [$F$ (2, 21) = 0.038; $p$ = 0.963 ns.; partial eta squared = 0.004]. This sits well alongside the two previous ANOVAs, highlighting that demand does not appear to affect the ability of tinnitus sufferers to deal with their own needs.

*Summary (Effectiveness)*

In addition to the above, it is helpful to reiterate the findings of this investigation into possible effects of demand on (self-reported) performance in tinnitus sufferers before moving on. As stated on page 205, it was appropriate to test for a relationship between demand and task performance - for tinnitus sufferers - as the findings of Study Two suggested the presence of something. There was a significant effect of overall demand (page 205), showing tinnitus suffers reporting moderate levels of such demand to be less satisfied with their overall performance than the other groups. Yet when the effectiveness measure was split into its three component parts, it was found that "effectiveness in getting things done" was not determined by varying levels of task demand. Such was also the case for the measure "effectiveness in taking care of own needs". However, "effectiveness in getting on well with others" was determined - at least in part - by demand levels. Though sporadic, when this did occur (see Figure 20, page 215), it showed the same distinction between moderate and low/high demand individuals as has been shown elsewhere previously. Those with moderate workloads report the most severe tinnitus. This indicates that for tinnitus sufferers at least, the more extreme levels of demand result in a better self-perception of the ability of the individual to work or socialise with others.

*Aggregate Data - Discussion*

So far, Study Three has raised a number of interesting points. The trait scores on page 180 show that the participants are comparable to the ones that took part in the earlier Studies. This is important, as it allows parallels to be draw between the three sets of conclusions. Here though, it would appear that the effect of demand on tinnitus severity is not broad. Further, it is clear that certain types of demand have a greater effect than others. In the original Demand hypothesis, it was only lunchtime demand that suggested an effect on tinnitus severity, and even then it was a delayed effect into the evening. Unexpectedly, it was tinnitus sufferers experiencing moderate levels of demand at lunchtime who were reporting more severe tinnitus in the evening (Figure 13, page 176), although in this particular case, these differences may not have been significant. This is due in no small part to the non-significance of emotional and physical demands. Logically, it was reasonable to suggest that all three types of demand would have the capacity to determine tinnitus awareness to some extent. Emotional processes result in increased activity within the limbic system, and this is due to the role that the limbic system plays in associating emotion with incoming sensory signals (Lockwood et al., 1998). In addition, it is well-documented that the limbic system has an important role in the maintenance of the central generation of the tinnitus sensation (Jastreboff, Grey, & Gold, 1996). Increasing emotional demand - which would no doubt be negative - could therefore be realistically expected to result in increased limbic activity, heightening tinnitus awareness either by allocation of increased attentional resources or increased signal strength. However, this was not seen to be the case - albeit with a small sample size - and for this reason, we do not need to further consider emotional demand at this time. Increased physical demand is likely to be due to physical activity. It is known that exercise has a positive effect on depression (North, McCullagh, & Tran, 1990; Tkachuk & Martin, 1999), and that higher levels of physical activity lead to reduced depression, both immediately and in the longer-term. Such a reduction could possibly have led to a decrease in subjective tinnitus severity as the two are linked, and that more depressive individuals tend to internalise and so concentrate more on themselves than the situation around them (Mathew & Weinman, 1981; Bridges & Goldberg, 1985). Of all the mental illnesses, clinical depression is the one that shows the most consistent positive response to exercise - in whatever form - with the most powerful effects being found amongst clinical populations (Martinsen, 1994). As such, there was a reasonable expectation of higher physical demand leading indirectly to a reduction in tinnitus severity. This was not found. There may be several reasons for this, not least of which was the nature of the aggregate data - with six weeks worth of results condensed together rather than monitored longitudinally. However, this in itself is an interesting question which could be returned to in future. Unlike many chronic conditions, tinnitus is not one that reduces individual ability to exercise (i.e. mobility problems) and while this Thesis focuses on the effects of tinnitus rather than treatment of it, this is an appropriate avenue for future research.

Only mental demands were found to play a part in the continual change in tinnitus severity, and there were real reasons for expecting level of demand (mental) to affect tinnitus perception. As stated previously, it is well-documented that attentional resources are finite (Kahneman, 1973), and it is assumed that awareness of the tinnitus sensation means that some part of these limited resources have been allocated to monitor it. The question remaining is that since tinnitus is known to fluctuate, is this due not only to physiological reasons, but also the level of mental resources available to focus on the tinnitus sensation for reasons previously described (Jastreboff et al., 1996; Kroener-Herwig et al., 2000)? Study Two encouraged the theory that the effect of tinnitus on performance is moderated by task demand. Here it was shown that low mental demands in both morning and evening resulted in less severe tinnitus at the end of the day. This is an important finding validating the diary method, not least because a laboratory study cannot practically show a delayed effect. No such consequence was highlighted for moderate/high mental demand, and the two significant effects were instead indicative of a more linear relationship; i.e. low mental demands resulting in reduced tinnitus severity (i.e. distress) and moderate/high demand resulting in comparably greater subjective tinnitus severity. Yet such distinctions can be explained away through the suggestion that the diary study may in fact be picking up on a separate process to the laboratory studies. The latter concerned immediate cause and effect, with the relationship between performance and tinnitus severity apparently moderated by difficulty. This study suggests a more delayed cost of higher mental demand, which results in the linear relationship described.

Importantly, the demand variables themselves were not immediate measurements and in that sense, may not have corresponded entirely with the tinnitus levels reported at those snapshot moments during the day. It is likely that the participants did not stop in the middle of complex processes to complete their diary then return to the task at hand. As such, levels of morning demand may not be entirely in sync with subjective tinnitus severity (morning). Hence, we more clearly see the delayed effect of demand making itself felt towards the end of the day, an accumulation of the costs of dealing with a higher workload, resulting in worsening tinnitus in the evening. Therefore, in order to ascertain whether or not both moderated and linear relationships exist side by side, it is best to look in more detail at what was referred to as the State Demand Hypothesis - long and short-term effects of specific activity. These three variables "concentration required", "effort demanded" and "time pressure felt" were each attuned to the very moment in which subjective tinnitus levels were rated and as such, may well be more accurate indications of the level of demand faced at that point in time. Time pressure appeared to have no effect. It was originally included as an attempt to differentiate between the Mackworth Clock Task (MCT) and the Grid Task in Study Two. Both were tasks of vigilance, both were shown to promote poorer performance in tinnitus sufferers, but the Grid Task was perceived to be more difficult for an unconfirmed reason (page 143). It was concluded that this may have been due to the fact that the Grid Task ran at a faster pace, or in other words, demanded response more rapidly, and so holding an extra sense of time pressure that the MCT did not. The lack of any visible effect of time pressure on tinnitus severity may thus support the notion that time pressure was not a factor, and that it was some quality of the MCT which resulted in an inability to perceive poor performance - as was suggested in the Study Two discussion. Furthermore, time pressure may not equate to actual pressure, so there is scope for attempting to define this factor more accurately. As such, this is an avenue for further study.

Yet both "concentration demanded" and "effort required" of participants were seen to have a consequence. Each of these particular variables can plausibly be linked to the one effective demand variable - mental demand - strengthening the case for tinnitus severity to be determined by attentional resources available and sub-consciously allocated to monitor the sensation. Taking "concentration required" first, we see a highly significant interaction between levels of concentration demanded (morning) and time of day (Figure 16, page 194). At first, this provides a confusing picture, but one that distances the effects of low concentration from moderate/high concentration. Here, low levels correspond with low levels of tinnitus that then rise during the day. Correspondingly, situations demanding more concentration result in high immediate tinnitus severity, but then reducing as time goes on. It is apparent yet again that there is an effect of morning variables on subjective tinnitus severity in the evening, something that a laboratory study could not show. The presence of a delayed effect is very interesting, particularly as it suggests the possibility of future prediction. However, we must be careful and be aware that other things can occur between morning and evening that can themselves have a major effect on what comes after. As will be seen later in discussion of the disaggregate data, that which happens immediately prior to the relevant time is often the most significant predictor variable. Yet Figure 16 (page 194) is strikingly similar to the significant interaction found for morning effort. Here, low levels of the demand variable resulted in lower immediate tinnitus but higher levels of tinnitus severity later on, with high levels of effort promoting the opposite effect. The only difference with this interaction is that tinnitus sufferers reporting moderate levels of effort declared higher levels of tinnitus severity, remaining unchanged across time. Therefore, with relevant variables, low/high demands promote different effects to moderate demands, although the direction of this relationship is not always consistent. It is probable the morning diary was filled in at breakfast or before leaving the house. For those participants reporting low requirements, workload would most likely increase during the course of the day. Conversely, a very busy start to the day would be more immediately stressful – rapidly promoting more severe tinnitus (Rizardo et al., 1998) - but would put the rest of the day in context. There is the sense from both interactions that moderate levels of effort and concentration promote higher, more constant levels of tinnitus. This is surprising as Study Two suggested beneficial effects of middling cognitive distraction (i.e. better performance) drawing resources away from the tinnitus sensation, but this newer finding is reinforced by the results of the mixed ANOVA investigating lunchtime effort levels. This saw a tendency towards a main effect on tinnitus severity – with post hoc tests confirming significant differences in tinnitus severity between participants reporting moderate and high levels of effort, and a tendency towards significance - $p < 0.1$ - for moderate/low effort (Figure 18, page 200).

Study Two showed that under moderate levels of demand - i.e. tasks of middling difficulty; the $O^3$ Task and the SAT - tinnitus sufferers performed at least as well as the control population. In the case of concentration and effort, it may have been that moderate demands led to better performance, resulting in some sort of increase in personal cost which later revealed itself in the form of worsening tinnitus (subjective). Looking back to the model of Kröner-Herwig et al. (2000), we know that the focusing of attention leads to a perception of worsening tinnitus. As such, a re-focusing of attention onto tinnitus after a challenging situation has been concluded, will have much the same effect. However, no evidence exists to show a linear relationship between performance levels (albeit self-reported) and tinnitus severity. Looking back to Study Two, it is unfortunate that while subjective tinnitus ratings were taken before the experiment and after each task, no final measurement was taken after the experiment had been concluded. If this had been done, more support may have been evident.

The correlation matrix investigating the Performance Hypothesis was quite straightforward. As would be expected, the various tinnitus and effectiveness measures correlated well with themselves, but not with each other. This indicates no direct relationship between tinnitus and performance, a result seemingly contradicted by Studies One and Two which showed performance decrements in tinnitus sufferers under certain conditions. Nevertheless, this is not the case. The fact that there is no direct relationship between tinnitus and performance is unimportant. Study Two in particular shows performance varying in tinnitus sufferers according to task demands. As such, it is the interaction between tinnitus and demand would appear to determine performance. That some moderating relationship exists - in terms of mental demands at least - is apparent.

Another, obvious advantage of the diary study was that all participants were tinnitus sufferers. For this reason, it was possible to look at the relationship between demand and performance (subjective) for people with at least a certain level of chronic tinnitus (Grade II or III - Klockhoff & Lindbolm, 1967). Overall, there was a significant main effect of demand on performance. Interestingly, low/high demand participants were again distinct from those reporting moderate demand ($p$ = 0.056 ns., and $p$ = 0.020 respectively). Figure 19 (page 209) illustrates this well, with tinnitus sufferers facing moderate levels of demand - and as is known, more severe tinnitus - reporting reduced performance, or at least that they perceive poorer performance on their part. After all, perception of poor performance is not the same thing as an actual performance decrement. Nevertheless, this relationship was consistent throughout the day. Since the precedent was set with the splitting up of demand into three subsets, it was also decided to split the performance variable (i.e. self-reported effectiveness) back into "getting things done", in "getting on well with others" and effectiveness in "taking care of own needs". These ANOVAs showed that there was no effect of demand on individual perception of success in accomplishing tasks or ensuring that personal needs were met. However, a significant interaction between lunchtime demands and time of day was reported with regards to effectiveness in getting along with other people. Tinnitus sufferers reporting the presence of low/high lunchtime demands felt that they were getting along better with other people than those sufferers facing moderate demands. As has already been said, the single most obvious explanation for this is the fact that tinnitus sufferers often struggle to contain a sense of general irritability (e.g. Jakes, Hallam, Chambers, & Hincliffe, 1985; Erlandsson, Hallburg, & Axelsson, 1992). Since this study has already seen that tinnitus sufferers under moderate levels of demand are those encountering the most severe tinnitus, it would seem prudent to put forward the idea that there is a connection between higher tinnitus levels and this self-perception of failing to get along with others. It is known that tinnitus sufferers report that they find it extremely difficult to relax (Tyler, Aran & Dauman, 1992). In addition to this, work on the Tinnitus Handicap Questionnaire (Kuk, Tyler, Russell & Jordan, 1990) was one of several to point out the social consequences of tinnitus, as well as the physical and emotional ones. Higher than normal - yet consistent - levels of tinnitus will lead to irritation, concentration difficulties and a reduction in speech redundancy - all suggesting a real increase in the effort needed to listen to and interact with others. Logically, this should equate to increasing tiredness and a sense of increasing difficulty. As the tinnitus asserts itself, more effort will be required and as such, performance levels will either drop, or the individual senses the need for extra effort to maintain performance.

To summarise, demand variables directly affecting tinnitus were limited. They included mental demand, concentration required and the effort demanded of participants at various points during their day. If anything, moderate levels of these variables resulted in levels of tinnitus severity significantly worse than for counterparts reporting low/high demands. In addition, moderate demands were linked with a perception of reduced effectiveness - specifically dealing with other people (lunchtime/evening). When coupled with the fact that early demands affect tinnitus severity later in the evening, this suggests that in some cases, cost is immediate and that in other situations, the effect is delayed. Consistent heavy demand across the whole day may have occurred from time to time for some or all of the twenty-four participants. However, the nature of aggregate data is that four weeks of data were averaged together and so - in this format - the results of such days have not been separately considered and have instead regressed towards the mean. It is possible to sift through the data and find these days but in all likelihood, they would be few and far between. Instead, it is proposed to look at the disaggregate data. The advantages of using a moderated hierarchal regression are clear, and will be discussed now.

*Disaggregate Data - Results*

In a separate methodology, the disaggregate data was assembled without regard to the individual participants. As with the aggregate data, weeks one and six were ignored - due to the same reasons - with week one used as practice and falling completion rates in week six. A major advantage of the disaggregate method is that each day can be compared to every other day. So all twenty-eight days were brought together, which could have resulted in a grand total of 672 rows of data (28 days x 24 participants), assuming 100% completion rate, more than enough to practically sustain a regression procedure.

Since regression is possible, it is clearly the most appropriate way to test the Moderated Interaction Hypothesis, namely that tinnitus severity - moderated by demand - determines performance. In particular, a moderated hierarchal regression as outlined by Aiken & West (1991) is particularly suitable. It has been recommended for twenty years as being the most appropriate method for testing main effects and interactions when independent measures are continuous (Parkes, 1991; Cohen, Cohen, West & Aiken, 1999). In addition, moderating effects should ideally be tested with moderated regression analysis (Landisbergis, 1988). Conditional effects are entered into the regression equation, followed by interactions between the main variables. Unfortunately, as Lynch (2003) states, the combination of two first-order variables (i.e. demand and tinnitus severity) can result in multicollinearity problems if they have a stronger relationship with each other than they do with the dependent variable (i.e. effectiveness). This is resolved by transforming the data, standardizing all variables before calculating the interactions (Jaccard, Turrisi & Wan, 1990). This results in the removal of all between person effects (Kessler, 1987) and a much lower correlation between the relevant variables (Carayon, 1993). In addition, due to the lack of power associated with moderated regression analysis (Aiken & West, 1991), it was decided to adopt a more liberal significance criterion of $p < 0.10$ (Pedhazur, 1982) to report the findings. Furthermore, for each regression, variables were entered in specific order. Due to the nature of the clinical population, participant numbers were understandably small. Using each day as separate event means the trait variables normally used as background factors in a regression were not included. There is simply too much repetition.

*Correlations*

Table 81

*Correlation matrix of standardised variables (n = 558)*

| Variables | TIN (night) | TIN (morn) | TIN (lunch) | TIN (evening) | DEM (morn) | DEM (lunch) | DEM (eve) | EFF (morn) | EFF (lunch) |
|---|---|---|---|---|---|---|---|---|---|
| Tinnitus (morn) | .465** | | | | | | | | |
| Tinnitus (lunch) | .241** | .321** | | | | | | | |
| Tinnitus (evening) | .237** | .305** | .355** | | | | | | |
| Demand (morn) | .048 | .073 | .049 | .073 | | | | | |
| Demand (lunch) | .009 | -.037 | .029 | .085 | .431** | | | | |
| Demand (evening) | .039 | .004 | -.039 | -.016 | .318** | .361** | | | |
| Effectiveness (morn) | -.108* | -.182** | -.192** | -.096* | .034 | .023 | -.010 | | |
| Effectiveness (lunch) | -.033 | -.100* | -.217** | -.088* | -.034 | .011 | .001 | .304** | |
| Effectiveness (evening) | -.096 | -.104* | -.142** | -.229** | -.069 | -.094 | .088* | .391** | .369** |

*p<0.05; **p<0.01.

The matrix shows a similar story to that of the aggregate data. The tinnitus variables, the effectiveness variables and the demand variables correlate well with themselves (e.g. tinnitus at lunchtime and tinnitus in the evening). In addition, it is noticeable that this time, consistent negative correlations exist between tinnitus severity and effectiveness, suggesting that increasing tinnitus severity is linked to reduced effectiveness. Furthermore, it can be seen that previous tinnitus levels remain significantly correlated to later performance levels (e.g. morning tinnitus severity and evening effectiveness).

For indicated reasons, trait variables were left unused in the following regressions. Yet since it is known that the value of a variable at any given point may be affected by its previous states (Bolger, Delongis, Kessler, & Schilling, 1991), those regressions searching for a relationship later in the day will also make use of earlier variables. For example, morning and lunchtime effectiveness will help predict evening performance levels.

The hypothesis section makes note of the Moderated Interaction Hypothesis. Disaggregate regression will help investigate this by showing: (a) the potency of demand and tinnitus severity as predictors of performance, and (b) the effect of tinnitus severity on performance - as moderated by reported demands.

*Predictors of morning performance*

The first step in predicting morning performance was determining the dependent variable (morning effectiveness). The next step was to use any previous variables. In this case, there was no previous measurement of performance, so the tinnitus rating from the night before was used instead. Next was the inclusion of current demand and tinnitus severity measures. Finally, the interaction between demand and tinnitus severity was included.

Table 82

*Summary of moderated regression analysis for morning effectiveness (n = 558)*

| Step | Variables | $R^2$ | $R^2$ change | Beta | p-values |
|---|---|---|---|---|---|
| 1. | Tinnitus severity (night before) | .012 | .012 | -.028 | .552 ns. |
| 2. | Demand (morning) | .036 | .024 | .053 | .205 ns. |
| | Tinnitus (morning) | | | -.172** | p < 0.01 |
| 3. | Demand x Tinnitus (morning) | .039 | .003 | -.048 | .256 ns. |

Note: table shows standardised beta weights for each step. * $p < 0.1$; ** $p < 0.01$.

As the matrix shows (page 229), morning demand did not predict morning effectiveness, though morning tinnitus did ($r$ = -.108; $p$ < 0.05). Table Eighty illustrates the incremental rise in $R^2$ and standardised beta coefficients. The overall model was significant [$F$ (4, 555) = 5.541; $p$ = 0.000], with 3.9% of the variance accounted for. There was one significant predictor variable - morning tinnitus severity (which originally correlated well with the DV). The direction is apparent too, with increasing tinnitus leading to reduced performance. From these results, it is suggested that there is only very limited support for the Moderated Interaction Hypothesis, and that this is due to the reported correlation and not the regression.

*Predictors of lunchtime performance*

In prediction of lunchtime performance, it is advantageous to first add morning performance to the model (Bolger et al., 1991). From there, previous (morning) demand and tinnitus levels were added, followed by current demand and severity measurements. Finally, previous and current interactions were also entered.

Table 83

*Moderated regression analysis to predict lunchtime effectiveness (n = 521)*

| Step | Variables | $R^2$ | $R^2$ change | Beta | p-values |
|---|---|---|---|---|---|
| 1. | Effectiveness (morning) | .094 | .094 | .271** | $p < 0.01$ |
| 2. | Demand (morning) | .100 | .006 | -.049 | .284 ns. |
| | Tinnitus (morning) | | | -.004 | .933 ns. |
| 3. | Demand (lunchtime) | .126 | .026 | .034 | .461 ns. |
| | Tinnitus (lunchtime) | | | -.177** | $p < 0.01$ |
| 4. | Demand x Tinnitus (morning) | .133 | .007 | -.079* | $p < 0.1$ |
| | Demand x Tinnitus (lunchtime) | | | -.003 | .942 ns. |

Note: table shows standardised beta weights for each step. * $p < 0.1$; ** $p < 0.01$.

The most significant model [$F$ (7, 521) = 11.238; $p$ = 0.000] accounted for 13.3% of the variance in lunchtime performance levels. This was mainly due to that explained by morning performance levels, but lunchtime tinnitus severity and the morning interaction between severity and demand were significant. In the case of the interaction, this would not normally be enough, but due to the more liberal policy adopted here (Pedhazur, 1982), it provides for a small but significant increase. Since it was deemed significant, it was appropriate to follow the procedures laid down by Cohen et al. (2003) and Aiken & West (1991), and run a simple slope analysis on whether demand moderates the relationship between tinnitus and performance.

Table 84

*Simple slope analysis investigating moderating effects of demand*

| Demand (moderator) | Simple slope of tinnitus severity on performance | SE | t(520) | Intercept |
|---|---|---|---|---|
| High | -.050 | .059 | .854 | .171 |
| Mean | .014 | .044 | .326 | .094 |
| Low | -.025 | .059 | -.420 | .012 |

Intercept = predicted value for effectiveness when morning tinnitus severity at centred mean (i.e. M = 0); * $p < 0.05$

The results of this analysis show that differing levels of morning demand do not affect the predictive power of morning tinnitus on lunchtime performance. Since the interaction was deemed significant, this was unexpected, but can be explained through the use of the more liberal significance criterion $p < 0.1$ (Pedhazur, 1982). As such, the Moderated Interaction Hypothesis can probably be discounted here, as would have happened if more stringent criteria were being observed.

*Predictors of evening performance*

Since a number of earlier measurements are available, this is the most complicated of the regressions. More lagged variables exist to be placed into the model. Previous effectiveness measurements were entered first, followed by demand and tinnitus variables for morning, then lunchtime, and finally evening. Last, all three demand x tinnitus interactions were entered; a total of eleven variables in five different blocks.

Table 85

*Moderated regression analysis predicting evening performance (n = 511)*

| Step | Variables | $R^2$ | $R^2$ change | Beta | p-values |
|---|---|---|---|---|---|
| 1. | Effectiveness (morning) | .233 | .233 | .317** | $p < 0.01$ |
| | Effectiveness (lunchtime) | | | .278** | $p < 0.01$ |
| 2. | Demand (morning) | .241 | .008 | -.077* | $p < 0.1$ |
| | Tinnitus (morning) | | | .033 | .444 ns. |
| 3. | Demand (lunchtime) | .246 | .005 | -.114* | $p < 0.01$ |
| | Tinnitus (lunchtime) | | | .037 | .394 ns. |
| 4. | Demand (evening) | .292 | .046 | .149** | $p < 0.01$ |
| | Tinnitus (evening) | | | -.174** | $p < 0.01$ |
| 5. | Demand x Tinnitus (morning) | .294 | .002 | -.042 | .297 ns. |
| | Demand x Tinnitus (lunchtime) | | | -.027 | .509 ns. |
| | Demand x Tinnitus (evening) | | | .007 | .861 ns. |

Note: table shows standardised beta weights for each step. * $p < 0.1$; ** $p < 0.01$.

In providing a significant model [$F$ (11, 488) = 18.044; $p$ = 0.000], the predictor variables accounted for 29.4% of the total variance in self-reported evening performance. Six of these were significant, with the lagged effectiveness variables being the most useful. All demand variables were significant - interestingly, morning and lunchtime demand have negative beta weights whereas evening demand has a positive beta value. This provides evidence of a time delay on performance, namely that personal performance in the evening is reduced due to the delayed effects of earlier demands – i.e. cost. Evening tinnitus severity variables were also of use. Nevertheless, the interactions between demand and tinnitus severity were not significant predictors.

The above regressions are clear in that predictions of the performance of tinnitus sufferers are helped most by taking account of recent ratings of effectiveness. Though the Moderated Interaction Hypothesis expected interactions to significantly add to the usefulness of the models, there was only partial support. This took the form of the morning interaction predicting lunchtime performance. Yet, as was discovered in the aggregate section, mental demand is a more potent form of demand in the case of tinnitus. As such, the regressions will be run again - with mental demands replacing general demand - to see if the models can be improved upon.

*Correlations (Mental demand)*

Table 86

*Correlation matrix of standardised variables (n = 558)*

| Variables | TIN (night) | TIN (morn) | TIN (lunch) | TIN (evening) | MDEM (morn) | MDEM (lunch) | MDEM (evening) | EFF (morn) | EFF (lunch) |
|---|---|---|---|---|---|---|---|---|---|
| Tinnitus (morn) | .465** | | | | | | | | |
| Tinnitus (lunch) | .241** | .321** | | | | | | | |
| Tinnitus (evening) | .237** | .305** | .355** | | | | | | |
| Mental Demand (morn) | -.015 | .066 | .034 | .038 | | | | | |
| Mental Demand (lunch) | .026 | -.024 | .007 | .100* | .403** | | | | |
| Mental Demand (eve) | .007 | -.065 | -.026 | -.025 | .287** | .365** | | | |
| Effectiveness (morn) | -.108* | -.182** | -.192** | -.096* | .075 | .020 | -.007 | | |
| Effectiveness (lunch) | -.033 | -.100* | -.217** | -.088* | -.021 | .022 | -.002 | .304** | |
| Effectiveness (eve) | -.096* | -.104* | -.142** | -.229** | .004 | -.061 | .103* | .391** | .369** |

*p<0.05, **p<0.01.

This correlation matrix shows no significant correlations between mental demand and tinnitus. It is very similar for mental demand and effectiveness too, though there is one significant correlation in the evening. However, this is very close to the earlier matrix (Table 81, page 229) for overall demand and the results were quite predictable, given that mental demand was always an aspect of general demand. However, mental demand was shown to be the variable having the greatest effect on tinnitus severity. And if this effect is a moderating one, it is unlikely that a strong linear relationship - i.e. a correlation - would be present.

*Predictors of morning performance (mental demand)*

With morning effectiveness the dependent variable, this regression incorporated tinnitus severity from the night before, followed by morning mental demand, tinnitus severity, and the interaction between them.

Table 87

*Moderated regression analysis for morning effectiveness - mental demand (n = 487)*

| Step | Variables | $R^2$ | $R^2$ change | Beta | p-values |
|---|---|---|---|---|---|
| 1. | Tinnitus severity (night before) | .006 | .006 | -.007 | .887 ns. |
| 2. | Mental demand (morning) | .031 | .025 | .092** | $p < 0.05$ |
| | Tinnitus (morning) | | | -.160** | $p < 0.01$ |
| 3. | Mental demand x Tinnitus (morning) | .034 | .003 | -.059 | .186 ns. |

Note: table shows standardised beta weights for each step. * p < 0.1; ** p < 0.01.

Using mental demand instead of general demand, the model provided a significant result [$F$ (4, 496) = 4.378; $p$ = 0.002], explaining 3.4% of morning performance variance - in comparison to the 3.9% accounted for by general demands. Here, the majority of the explained variance is due to morning mental demand and tinnitus severity. The interaction was not significant.

*Predictors of lunchtime performance (mental demands)*

The prediction of lunchtime performance by tinnitus severity and mental demand retained the use of lagged morning effectiveness. In addition, morning mental demand and tinnitus severity were added, followed by lunchtime mental demand, corresponding tinnitus levels and the two interactions.

Table 88

*Lunchtime effectiveness as predicted by the (mental) demand/tinnitus model (n = 453)*

| Step | Variables | $R^2$ | $R^2$ change | Beta | p-values |
|---|---|---|---|---|---|
| 1. | Effectiveness (morning) | .075 | .075 | .253** | $p < 0.01$ |
| 2. | Mental demand (morning) | .079 | .004 | -.063 | .198 ns. |
| | Tinnitus (morning) | | | .012 | .794 ns. |
| 3. | Mental demand (lunchtime) | .104 | .025 | .050 | .308 ns. |
| | Tinnitus (lunchtime) | | | -.160** | $p < 0.01$ |
| 4. | Mental demand x Tinnitus (morning) | .108 | .004 | -.046 | .320 ns. |
| | Mental demand x Tinnitus (lunchtime) | | | -.036 | .433 ns. |

Note: table shows standardised beta weights for each step. * $p < 0.1$; ** $p < 0.01$.

The regression produced a highly significant model [$F$ (7, 463) = 7.897; $p$ = 0.000], accounting for 10.8% of the total variance of lunchtime performance in tinnitus sufferers. Previous effectiveness ratings were again significant; alongside lunchtime tinnitus severity. Interactions provided no significant addition to the model, meaning that the best predictors available were previous (morning) performance levels and current tinnitus severity.

*Predictors of evening performance (mental demands)*

Prediction of evening performance required a near identical copy of the earlier evening regression, but with mental demands replacing general demand throughout, as would be expected. This would also affect the interactions. Both morning and lunchtime effectiveness were entered first, followed by mental demand and tinnitus severity in morning, early afternoon, and evening. Interactions were then entered, a total of eleven predictor variables in five blocks.

Table 89

*Moderated regression analysis predicting evening performance (n = 436)*

| Step | Variables | $R^2$ | $R^2$ change | Beta | p-values |
|---|---|---|---|---|---|
| 1. | Effectiveness (morning) | .220 | .220 | .318** | $p < 0.01$ |
| | Effectiveness (lunchtime) | | | .269** | $p < 0.01$ |
| 2. | Mental demand (morning) | .220 | .000 | -.017 | .716 ns. |
| | Tinnitus (morning) | | | .015 | .748 ns. |
| 3. | Mental Demand (lunchtime) | .224 | .004 | -.084* | $p < 0.1$ |
| | Tinnitus (lunchtime) | | | .049 | .284 ns. |
| 4. | Mental demand (evening) | .261 | .037 | .124* | $p < 0.1$ |
| | Tinnitus (evening) | | | -.145** | $p < 0.01$ |
| 5. | Mental demand x Tinnitus (morning) | .271 | .010 | -.017 | .705 ns. |
| | Mental demand x Tinnitus (lunchtime) | | | -.039 | .388 ns. |
| | Mental demand x Tinnitus (evening) | | | .097* | $p < 0.05$ |

Note: table shows standardised beta weights for each step. * $p < 0.1$; ** $p < 0.01$.

This final moderated regression resulted in another highly significant model [$F$ (11, 436) = 14.359; $p$ = 0.000]. It accounted for an impressive 27.1% of the total variance in evening effectiveness scores - roughly comparable to the 29.4% of the general demand regression (page 235). In both cases, lagged effectiveness variables were of real use. They also shared significant predictor variables in the form of lunchtime and evening demand, and evening tinnitus severity. Yet the real difference is the fact that the evening interaction is significant here, suggesting that mental demand may indeed moderate performance in tinnitus sufferers under certain circumstances. A simple slopes analysis was required to ascertain just how this interaction functions (Aiken & West, 1991; Cohen et al. 2003), the hypothesis being that the relationship between tinnitus severity and performance is moderated by mental demand.

Table 90

*Simple slope analysis - investigation of the moderating effect of evening mental demand*

| **Mental demand (moderator)** | **Simple slope of tinnitus severity on performance** | **SE** | **t(435)** | **Intercept** |
|---|---|---|---|---|
| High | -.228 | .057 | -4.021** | -.108 |
| Mean | -.143 | .046 | -3.111** | .004 |
| Low | -.059 | .062 | -.952 | .117 |

Intercept = predicted value for effectiveness when evening tinnitus severity at centred mean (i.e. M = 0); * $p < 0.05$, ** $p < 0.01$.

Unlike the earlier interaction (page 233), this one was much more significant. Due to this, the simple slopes analysis has produced a much clearer and significant result. Table 90 shows the relationship between evening tinnitus severity and evening performance to be significant in the presence of high and average (moderate) demand. There is no such relationship in the presence of low demands.

*Disaggregate Data - Discussion*

The findings of the regressions are remarkably consistent. In each and every regression, current levels of tinnitus have been a significant predictor of self-reported effectiveness. Demand on the other hand, was less useful. General demand was only of use in predicting evening performance (Table 85, page 234), but when it was, it was a significant predictor variable throughout the day, even way back in the morning when the more liberal criterion allowed its inclusion. Mental demand was better, being a significant predictor of morning effectiveness. In addition, lunchtime and evening mental demand were significant predictors of evening effectiveness. However, unlike tinnitus severity, there is a sense of delay in the effect that demand has. Immediate performance - if affected - is more often than not predicted by previous demand, and rarely current demand. In addition, demand and mental demand are most likely to be predictors in the evening - towards the end of the day. This takes us back to the idea of there being a cost in the maintenance of higher level performance, as first raised in the aggregate section. It is a staple belief of Occupational Psychology (e.g. Hockey, 1997; Wickens & Hollands, 2000) that the individual has to strive to maintain orientation towards primary task goals. Doing so results in side-effects such as strain and degradation in performance of other tasks. With regards to tinnitus, it has been proposed earlier that higher demands lead to a problem with the allocation of finite mental resources (Kahneman, 1973; Mühlnickel et al., 1998), resulting in more severe tinnitus. The increased tinnitus sensation is thus more potent, more distracting, and results in poorer performance. Importantly, this effect is not immediate. (Mental) demands earlier in the day lead to a struggle to maintain performance which is then reflected in a later increase in tinnitus severity, in turn resulting in an immediate loss in performance. However, such a theory requires proof that demand indeed moderates the relationship between tinnitus and performance. From the above, support for the Moderated Interaction Hypothesis is partial.

There are a number of reasons as to why this could be so. Sample size is not one of them due to the nature of the disaggregate data set. However, moderated hierarchical regression is a method known to have its difficulties (Aquinis, 1995). For example, numerous researchers (e.g. Evans, 1985; Morris, Sherman, & Mansfield, 1986) argue that testing hypotheses which predict the existence of moderating variables often have very low statistical power. If power is low, Type II statistical error rates are high and as such, researchers may mistakenly dismiss models that include moderating effects. In other words, in low power conditions, a conclusion stating that no moderating effect exists may well be incorrect. This makes the discovery of the moderating effect of evening mental demand all the more remarkable. If anything, it suggests that amongst others, the near-significance of the lunchtime interaction (general demand) may be worth more discussion than would otherwise be apparent. Yet, the very definition of a moderating relationship is that it occurs only under certain circumstances. It would be very easy to think that this relationship is a constant one, but there is no reason why this should be the case. That the one confirmed interaction takes place in the evening is no accident. The aggregate results show that on the whole, tinnitus flucuations during the course of a single day are minor - though it is known that tinnitus can fluctuate more wildly between days (Stouffler & Tyler, 1990). However, it is probable that demand changes much more fluidly, and it is this that probably resulted in the findings of Goodwin & Johnston (1980), whereby within-session fluctuations were discovered. It is not that the tinnitus sensation changes over a short period of time, but that awareness of it does in relations to the mental resources avilable to orientate to it. By the end of a whole day, any individual will have encountered a variety of situations and challenges, some active, some more passive, and it is these that moderate performance. The significance of high and moderate mental demand (Table 90, page 240) show the relationship between tinnitus and performance to be stronger in their presence than in the case of low demand. Possibly, it takes a continuous build-up of demand to reach the levels required to affect the evening relationship between tinnitus and task performace. Nevertheless, the issue could be more confusing still. With the diary being the size it was, it is clear that this Thesis must stick stringently to the chosen hypotheses, certainly with the space available. Yet, there is an argument for seeing in future research whether earlier demand moderates the later relationship between performance and the tinnitus sensation. In other words, whether or not the interaction between lunchtime demands and evening tinnitus severity (for example) predict personal effectiveness. The possibility adds another level to what is almost certainly a very complex relationship.

Nevertheless, this Thesis has proved that such a relationship does exist, with partial support of the hypothesis clear. Future research should not concentrate so much on attempting to provide more support for the hypothesis, but should instead seek to adjust the hypothesis to take account of these findings.

## GENERAL DISCUSSION

Through a need for clarity, the previous discussion sections have talked through the results of each study separately. However, these results cannot and should not be taken in isolation, as they are all part of an investigation into the same phenomenon, and this Thesis has progressed from one Study to the next for specific reasons. However, a lot of material has been discussed and in order to explain the basis behind the final conclusions, it is necessary to summarise previous research into the tinnitus sensation and the research found here.

Research into tinnitus has not been without its problems. Firstly, as has been seen, great effort was expended to establish a relationship between objective tinnitus severity and the distress caused by the condition (e.g. Stouffler & Tyler, 1989; Vernon, 1992). This failed, yet many researchers noted general tinnitus characteristics (e.g. Meikle & Griest, 1987; Meric et al., 1998) and agreed upon a number of consequences of chromic tinnitus. These include: anxiety; depression; and concentration difficulties (e.g. Sullivan et al., 1998; Folmer et al., 1999).

As research progressed, theories of tinnitus generation gradually became more sophisticated (e.g. Jastreboff, Grey, & Gold, 1996; Kröner-Herwig et al., 2000), and with them came the realisation that the tinnitus sensation is not generated in the periphery alone (i.e. the ear), and that instead, orientation and emotion systems are involved (Mirz et al, 1999). Furthermore, the work of Münickel et al. (1998) identified that areas of the auditory cortex concerned with the frequencies of the tinnitus sensation expand at the sake of others, providing more resources to focus on the noise at the expense of other activities. From this, we are lead to the pioneering work of Andersson et al. (2000), who identified that under certain conditions - i.e. the Stroop paradigm – tinnitus sufferers perform worse than a matched control group. That paper was the original inspiration for this Thesis. In part, this was due to certain methodological considerations. Importantly, the sample pool was limited. As stated earlier, chronic tinnitus is found in 6-20% of the population (Chung et al., 1984; Coles, 1987). Beyond this, a clinical population needed to be identified, and to have tinnitus severe enough to confirm to the more severe tiers of the Klockhoff and Lindblom grading scale (1967). This is a reduced number of individuals but it is believed that persistent and troublesome tinnitus is reported in roughly 1-5% of the UK population (Chung et al., 1984; Davies & Rafaie, 2000). This was constraining, not least because the original desire was to have a number of experimental groups in the laboratory: a control group; tinnitus sufferers; masked (temporarily) tinnitus sufferers; and a non-tinnitus sample with tinnitus sounds being played to them during experimentation. However, this turned out to be impractical for a number of reasons. Firstly, it took time to gain access to enough tinnitus sufferers for one experimental group, let along two of them. Secondly, as has already been discussed, masking is a particularly subjective treatment (e.g. Figure 6, page 63) that has uncertain effects which cannot be predicted (e.g. Vernon et al., 1990; Andersson & McKenna, 1998). Furthermore, it was stated by McFadden (1982) that tinnitus - an internal noise - may not be comparable to an external noise, however closely it was structured to mimic tinnitus. In addition, tinnitus is a highly subjective complaint with most tinnitus sufferers reporting different sounds with many different characteristics (Meikle & Taylor-Walsh, 1984) so a comparable laboratory condition would be next to impossible to validate. For these reasons, it was decided to simply compare tinnitus sufferers with matched controls on a variety of cognitive tasks, while at the same time measuring a number of trait variables to see if the presence of tinnitus resulted in increased anxiety, depression etc. as was the case with the majority of the research literature (e.g. Sullivan et al., 1998). Surprisingly, the presence of tinnitus had no effect on traits (Study One), meaning for all intents and purposes, the only difference between the two populations was the presence – or not – of tinnitus.

The most unusual result of Study One was perhaps that of the State Fatigue Inventory (Figure 7, page 91). Here, the control group was originally less fatigued (state) than the tinnitus sufferers but tired during the course of the experiment. By the end of the four tasks, both groups were comparably fatigued. Although this interaction was not replicated in Study Two (Table 28, page 142), this could be explained by the differences between the studies. Furthermore, the tiring of the control groups is clear evidence that the experiments were mentally tiring, and provides some support for the notion that tinnitus sufferers tend to be more tired at any particular moment. Certainly, this is important as Rizzardio et al. (1998) state that tinnitus becomes more noticeable when the individual is: tired; ill; facing emotional conflict; or when it is simply later in the day. Increasing fatigue leads to greater tinnitus awareness and so increases its power as a distracter, thus indirectly affecting performance.

The Study One experiments saw tinnitus sufferers performing significantly slower on the OMO task (rule of letter); tending to respond slower on the SAT ($p = 0.056$ ns.; page 108); and a similar slower response on the Stroop paradigm ($p = 0.074$ ns.; page 113). Furthermore, the slower – yet as accurate – responses of the tinnitus sufferers are nicely illustrated by the Vienna Determination Task (Table 21, page 109). Here, the distinction between "correct" and "delayed" responses aptly illustrate that some property of tinnitus is making use of the cognitive resources needed. In addition, the incongruent stimuli of the Stroop task (i.e. the hardest) also promoted more errors in the tinnitus population.

In comparison, Study Two was slightly different. It saw a performance decrement in both the Grid Task and the MCT on the part of tinnitus sufferers but here, it took the form of errors made, not response time. As such, the presence of tinnitus is still having an effect, and is most certainly causing problems in capacity. The SFI results show the tinnitus sample to be more tired on completion of Study Two than Study One. This suggests that Study Two was more demanding and as such, that this increased demand resulted in something slightly different happening. It would appear that as difficulty increases, the tinnitus signal results in slightly slower processing. As it increases further, this results in more mistakes – as seen in Study Two and supported in Study One by the mistakes made on incongruent Stroop stimuli. This idea of resources being misallocated is supported by the strong correlation between tinnitus severity (STSS) and errors made (Table 39, page 155).

Furthermore, the other big addition to Study Two was the request for difficulty ratings and tinnitus awareness on task completion. These confirmed the MCT to be the easiest task, and the Grid Task to be the hardest – especially so in the case of the tinnitus group (Table 29, page 143). As such, it is immediately apparent that the tasks most affected by the presence of tinnitus were the easiest and the hardest available. Two explanations exist. The first is the nature of the tasks themselves. Unlike the others, the MCT and the Grid task were tasks of vigilance requiring responses in certain circumstances only, whereas the SAT and the $O^3$ task required responses to each and every presented trial. It could be this need for constant vigilance that the tinnitus sensation interferes with. After all, the tinnitus sufferer is constantly seeking to ignore the noise, or to not concentrate on it, etc. The fact that the two tasks are similar may lead to cognitive interference (Wickens, 1984, 1991). Further research on the nature of the cognitive decrement is advised and is an excellent avenue for future investigation. It is of great importance to identify specific situations in which tinnitus is most problematic, and indeed, to show where presence of tinnitus is not a hindrance in daily life. Nevertheless, a conscious decision was made to put this avenue of approach to one side, and to return to it at a later date. Instead, for reasons already given, it was decided to focus on the second of those possible reasons for the specific nature of the decrement, the level of task difficulty, and so by definition, the level of demand faced by the individual.

The need, therefore, was to create a situation whereby all levels of demand would occur in a way so that tinnitus severity and measures of performance (i.e. self-reported effectiveness) could be measured. Hence, Study Three. By nature of the variables investigated, the Aggregate section was large, but significant results were mostly confined to a few variables. Comparable scores on the trait variables meant that comparisons could be drawn between the tinnitus sufferers in all three studies. The first finding was the trend of moderate lunchtime demand leading to higher levels of tinnitus severity in the evening (Figure 13, page 176). The important point here is how we define "moderate demand". While it was the middle third of reported demand from the collected diary pages, it may also be true that it was a time where full or near full cognitive capacity was reached, hence a delay before the true impact of the effort expended. In turn low demand would be the times when resources are spare, and high demand reflects those times when comfortable maximums are breached, resulting in immediate worsening of tinnitus (Study Two: Figure 11, page 145). It is the case that the Grid Task resulted in an immediate worsening of tinnitus, and also, that the MCT brought about the only other level of tinnitus severity that was not significantly different. From this, it may be suggested that the effects of low and high demands are immediate, but that the effects of moderate demand are either minimal or delayed - in which case they are hidden from the scope of a laboratory study.

Further, Study Three answered questions relating to the different types of demand, showing that it is mental demands that most interfere with performance, or at the very least, personal perception of performance. Table 67 (page 204) shows the summary of the results of the Demand Hypothesis. Figure 14 (page 184) shows the importance of low mental demand at the start of the day to reduce tinnitus at the end of it. Figure 15 (page 187) shows a more immediate of high demand – more severe tinnitus – and reiterates the helpfulness of low demand. This is further supported by the significant results attributed to the state variables of "effort demanded" and "concentration required", both closely related to the concept of mental demand. It is further evidence that low/high levels of demand result more severe tinnitus later in the day. Yet while it goes in the same direction, this does not sit well with the more severe tinnitus reported in the immediate aftermath of the Mackworth Clock task (Study Two). Nevertheless, the MCT provoked more severe tinnitus and also produced one other notable result; that the tinnitus group reported the task as being easy even though their performance was actually quite poor (more errors made).

The "effort demanded" and "concentration required" variables can be considered to be very similar to the concept of mental demand – though it must be remembered that the answers to these questions were immediate (i.e. a report of the last fifteen minutes) and as such must be considered as snapshots rather then evidence of more general trends. Therefore, it may well be that these variables are as close as the diary study can get to laboratory conditions. These significant results (found in detail in Table 69, page 206) tell of low morning demands gradually increasing tinnitus severity as the day goes on (Figure 16, page 194; Figure 17, page 198). Consequently, these results could highlight why low levels of demand manage to impact so powerfully on performance in the Mackworth Clock Task (tinnitus sufferers).

Table 70 (page 207) shows a significant and negative correlation between morning tinnitus severity and lunchtime effectiveness. In other words, there is support here for the concept of worsening tinnitus impacting negatively on later performance. In addition, Table 39 (page 155) shows that more severe (trait) tinnitus leads to a greater performance decrement on certain tasks. It was also shown that demand levels do affect personal perceptions of performance – or more specifically, effectiveness in getting along with other people (Figure 20, page 215). Here, moderate demands resulted in a consistently reduced perception of the ability to get along with other people, and high demand saw a gradual slump. In the case of moderate demand, this may be explained by the distracting nature of the situation at hand. Yet in the case of high demand, this is no doubt this is due to the fact that the tinnitus sufferers in question were being pushed, and as is well-documented, then become more irritable as concentration difficulties increase (Meikle et al., 1984).

The Disaggregate data used a different methodology, and as such, allowed a different view of the relationship between tinnitus and performance. In addition, as previously noted, moderated hierarchical regression lacks statistical power (Aiken & West, 1991). Therefore, a significant result - even if explaining a limited amount of variance - is important. Overall, personal performance was in part driven by earlier performance. Something to be expected as a subjective judgment would naturally pay attention to recent success/failure. Yet, evidence from Study Two suggested that demand moderates performance in tinnitus sufferers. The first series of regressions used demand as a predictor variable. Reported demand was only useful in the prediction of evening performance (Table 85, page 234), again providing evidence of its delay. There was a suggestion of a significant interaction between tinnitus and demand levels predicting lunchtime effectiveness (due to adoption of $p < 0.1$), but with minimal statistical power, no interaction was found. However, it is clear that mental demand is a more relevant variable than overall demand so it was certainly worthwhile repeating the regressions using mental demand instead. Mental demand was more useful by itself (Table 87, page 237) but even more so in prediction of evening performance (Table 88, page 238) where the interaction of evening demand and evening tinnitus severity provided a highly significant predictor variable. This showed that in the presence of moderate and high demand, tinnitus severity does affect performance. This is a very important result and supports much of what has already been said.

In conclusion, it is possible to bring together the findings of this Thesis into a coherent whole. Although it was not across the board due to the need for small clinical samples and such like, these studies have provided proof that tinnitus severity impacts on cognitive performance. The reasons for this are clear. The above show that low, moderate and high mental demands result in perceptions of tinnitus severity that are different to each other. The only confusion is the form that this relationship takes. For example, in the case of the laboratory studies, low and high demand result in increased tinnitus perception when compared to moderate demands. For concentration required (Figure 16, page 194) and effort demanded (Figure 17, 198), low demands immediately result in less subjective tinnitus severity than moderate/high demands. Different again are the results is lunchtime effort (Figure 18, page 200). It shows the individuals facing moderate demands are reporting more severe subjective tinnitus levels. In addition, it is the only situation not showing a delayed effect of low and high demand (i.e. a change in tinnitus awareness over time). There must be a reason as to why this is so, but please note that the moderately challenged group are reporting a tinnitus very slightly more than three out of five, namely tinnitus "no louder or quiet than normal" (see Appendix C). The difference between the effect of moderate demand and low/high demand is still there and it may just be that the others are in a state of flux that was not caught in the diary snapshot.

Furthermore, it must be reiterated that at all times, tinnitus measurements were subjective. For this reason, it has been impossible to distinguish between severity of the sensation and awareness of the sensation. Tinnitus is known to fluctuate during the course of the day (Andersson, Lyttkens & Larsen, 1999), but it is not known whether it is actually due to the refocusing of attention due to constantly changing allocation and reallocation of cognitive resources. Further, Study Three also made use of self-reported performance measures. In Study One and Study Two, reaction time and errors made were objective measurements of performance, but here effectiveness ratings were purely subjective. Nevertheless, they are representative of personal opinion in the same way that tinnitus distress is. Perception of personal effectiveness is just as important for the state of well-being as effectiveness is. And if these results instead point to the effect that increasing tinnitus awareness has on perceptions of effectiveness, it still amounts to much the same thing - distress.

These results suggest that moderate levels of demand do not appear to affect tinnitus severity or impinge much on personal performance. Low levels of tinnitus severity would seem to result in spare capacity orientating towards the tinnitus sensation and gradually enhancing it, supporting earlier findings that tinnitus becomes more of a problem on retirement, when trying to sleep and so on (e.g. Meikle et al., 1984; Tyler et al., 1992), as no distraction is present. Furthermore, consistent lack of activity is related to depression and there are many papers that strongly link tinnitus with depression, though arguments remain as to whether tinnitus may result in depression, or vice-versa (e.g. Harrop-Griffith et al., 1997; O'Connor et al., 1987; Dobie & Sullivan, 1998). In addition to this, high levels of demand would seem to provoke immediate increases in tinnitus severity as the individual becomes aware of the need for more resources while at the same time becoming more aware that not enough is available. In fact, it may be that the performance decrement seen in tinnitus sufferers (e.g. Incongruent Stroop stimuli and the Grid Task) is down to the fact that non-sufferers have greater spare capacity. Not being able to perform to optimum levels may be a reason for the excessive tiredness reported by tinnitus sufferers, but this may be due to the insomnia (Meikle et al., 1984) resulting in a less refreshing nights sleep.

Therefore, it is suggested that in treatment of tinnitus, the sufferer must not avoid activity. As mentioned previously, it would be of interest to investigate the possible beneficial effects of exercise on depression (North, McCullagh & Tran, 1990; Tkachuk & Martin, 1999), and the benefits that should activity would have on retired or unemployed tinnitus sufferers especially. In addition, since tinnitus is recognized as a disability both here and in Germany, (Kröner-Herwig et al., 2000), it is emphasized that there are numerous situations in which tinnitus sufferers perform comparably to people without the condition. It is likely that high demand causes the most problems, especially since tinnitus would seem to cause continual re-orientation to the signal and as such, caps the cognitive potential of most tinnitus sufferers - and indeed, this is an avenue for further study. Are the upper attentional limits of the tinnitus sufferer less than the non-sufferer, and if so, is this difference related to tinnitus severity? Further, are vigilance tasks - or others like them - particularly good at highlighting these deficiencies? This author would like to return to this idea in future and would encourage others to do so. A selection of vigilance tasks - encompassing a broad range of difficulties - would be able to answer this question if the tinnitus sufferers in question are compared to a control group. Furthermore, with the higher standard deviations reported throughout Study Two, it would be most useful to have enough tinnitus sufferers available to create both a help-seeking and a non-help seeking sample (Kirsch et al., 1989; Erlandsson et al., 1991) to compare this with each other as well as a control group to see if a clear lack of habituation makes the performance decrement greater, or heightens the moderating effect of demand on cognitive performance.

The main weakness of this Thesis was the small sample sizes ($n = 40$; $n = 36$; $n = 24$). This was hard to avoid with perhaps 5% of the population having chronic tinnitus at the required subjective severity. Further, the majority of tinnitus sufferers are middle-aged or older – as was seen with an average age of more than forty in all studies. This meant that normal samples – i.e. university students – were not appropriate. As such, volunteers had to be sort through audiology clinics, self-help groups and so on. Beyond this, tinnitus sufferers were not necessarily keen to take part. When they were, they were very approachable, helpful and most willing to put themselves out to come to the laboratory, fill in the diary and so on. However, a substantial number of those approached were unwilling on the basis that taking part in an experiment about tinnitus made them think more about their own tinnitus, consider its impact on their lives and actually make their tinnitus worse. Other conditions – e.g. dyslexia – are not subjective and do not get worse due to a focusing of attention on the condition. This is not the case with tinnitus, as focusing of attention can result in increasing distress (Figure 4, page 45; Kröner-Herwig et al., 2000). A number of possible participants were reluctant to take part for this reason, reducing the available sample population and, as such, the number of appropriate statistical methods available. It is hard to see how this problem can be avoided in future. Given the luxury of time, it would be easier to find more volunteers but many of the studies mentioned in their Thesis (e.g. Andersson et al., 2000) have used small samples. The ones that do not (e.g. Vernon, 1978; House 1981) has access to tinnitus clinics, with the researchers being clinicians based there. Even then, most data was gathered over a number of years. Researchers into tinnitus – particularly ones looking for performance decrements and other negative side-effects of tinnitus – will have to be aware that small samples sizes are to be expected without long periods of data collection.

It is hoped that more laboratory research will take place in deciding whether tinnitus sufferers are weak at vigilance tasks (e.g. Grid Task, MCT) or whether it is the lower/higher workloads that cause the performance decrement. It is hoped that in the future, the author will use vigilance tasks across a range of difficulty levels so see whether performance is uniformly poor or whether it is indeed moderated by task difficulty. Further, it is possible to take the diary study further and perhaps even use it in more continuous fashion. For example, through the use of electronic equipment to monitor both demands on the individual and subjective tinnitus levels. Here, the participant could wear an electronic device on the wrist or around the neck and at set intervals, be prompted to report relevant variables on a Likert scale. Say, once every hour or once every three hours depending what the optimum conditions may be to promote accurate and ongoing responses. This also opens up other avenues of approach. What is needed is a situation where demand slowly changes over time. Whether it increases or decreases is less important than the ability to measure tinnitus levels during a continuing period of change. Since an electronic diary is likely to be less intrusive, it may be possible to follow a middle-aged distance runner. A marathon or a half-marathon is an example of constantly changing demands, increasing over time. Since running is an activity still available and common to the middle-aged, it may be worthwhile to monitor tinnitus perception during a long run to see how changing demand affect subjective tinnitus levels. In less immediate fashion, it would be of interest to measure demand in individuals at the end of a contract, whether they are entering retirement, going on holiday or signing on as unemployed. The opposite is also true, perhaps monitoring unemployed tinnitus sufferers in such a way, and seeing the effect that restarting work may have on their condition. From the above, it is assumed that re-starting work will up demand and provide a more potent distracter, reducing tinnitus distress. However, a hard job or a promotion to a position of greater responsibility may worsen tinnitus distress and impact on performance.

Finally, it has already been mentioned that there is a significant correlation between reported tinnitus distress and the number of errors made on the Grid Task and the Mackworth Clock Task. Importantly, no research has attempted to ascertain a relationship between objective tinnitus levels and task performance. Is the performance decrement of tinnitus sufferers caused by subjective severity alone? There is support for this notion in Study Two (Table 39, page 155) but if a relationship does exist between objective and subjective tinnitus levels, then it may be the case than objective measurements are a more accurate predictor yet, or more likely, that objective and subjective levels together are accurate predictors of performance. Since the STSS can be used to roughly predict the number of errors made on the Grid Task and the MCT, then it is also possible to use task performance to predict subjective distress levels. While the MCT would have to be of a certain length to be effective, a short version of the Grid task may well be a useful diagnostic tool to illustrate the distress that caused by tinnitus in a particular individual. However, since even performance can be falsified, it does not sidestep the problems in effectively identifying the amount of distress that the tinnitus sufferer is under. For example, tinnitus is a byproduct of industrial noise, one that would allow a tinnitus sufferer to sue their employer if it can be proved that: (a) the tinnitus exists, and (b) that it is causing signifcant distress. A version of the Grid Task could be used in such circumstances. However, it would be useless in the face of a falsified performance on the part of the individual concerned.

All in all, there are a number of interesting ways in which the results of this Thesis can be built on in future. Many questions remain, yet it is hoped that this Thesis will provide further fertile ground for research into what has been aptly described as a "complex disorder of perception" (Thomas, 1993).

REFERENCES

Affleck, G., Tennen, H., Pfieffer, C., & Fifield, J. (1987). Appraisal of control and predictability in adapting to a chronic disease. *Journal of Personality and Social Psychology*, 53(2), 273-279.

Aiken, L. S., & West, S. G. (1991). *Multiple Regression: Testing and Interpreting Interactions.* Newbury Park, CA.: Sage.

Andersson G, Eriksson J, Lundh LG, Lyttkens L. (2000). Tinnitus and cognitive interference: A Stroop paradigm study. *Journal of Speech, Language and Hearing Research*, 43(5), 1168-1173.

Andersson G, Khakpoor A, Lyttkens L. (2002). Masking of tinnitus and mental activity. *Clinical Otolaryngology*, 27(4), 270-274.

Andersson, G., Kinnefors, A., Ekvall, L., & Rask-Andersen, H. (1997). Tinnitus and translabyrinthine acoustic neuroma surgery. *Audiological Neuro-otology*, 2, 403-409.

Andersson, G., Lyttkens, L., & Larsen, H. C. (1999). Distinguishing levels of tinnitus distress. *Clinical Otolaryngology*, 24(5), 404-410.

Andersson, G., & McKenna, L. (1998). Tinnitus masking and depression. *Audiology*, 37, 174-182.

Aquinis, H. (1995). Statistical power problems with moderated multiple regression in management research. *Journal of Management*, 21, 1141-1158.

Arnold, W., Bartenstein, P., Oestreicher, E., Roemer, W., & Schawaiger, M. (1996). Focal metabolic activation in the predominant left auditory cortex in patients suffering from tinnitus: A PET study with (18F) deoxyglucose. ORL (Basel), 58, 195-198.

Attias, J., Pratt, H., Reshef, I., Bresloff, I., Horowitz, G., Polyakov, A., & Shemesh, Z. (1996). Detailed analysis of auditory brainstem responses in patients with noise-induced tinnitus. *Audiology*, 35, 259-270.

Attias, J., Shemesh, Z., Bleich, A., Solomon, Z., Bar-Or, G., Alster, J., & Solmer, H. (1995). Psychological profile of help-seeking and non-help-seeking tinnitus patients. *Scandinavian Audiology*, 24, 13-18.

Axelsson, A. & Ringdahl, A. (1989). Tinnitus - a study of its prevalence and characteristics. *British Journal of Audiology*, 23, 53-62.

Banks, S. M. & Kerns, R. D. (1996). Explaining high rates of depression in chronic pain: a diathesis-stress framework. *Psychology Bulletin,* 119, 95-110.

Baskill, J. L. & Coles, R. R. A. (1999). Relationships between tinnitus loudness and severity. In: Proceedings of the Sixth International Tinnitus Seminar, Cambridge, UK. British Society of Audiology.

Beard, A. W. (1965). Results of leucotomy operations for tinnitus. *Journal of Psycosomatic Research,* 9, 29-32.

Beck, A. T. (1967). *Depression: Causes and treatment.* Philidelphia: University of Pennsylvania Press.

Beck, A. T., Rush, A. J., Shaw, B. F., & Emery, G. (1979). *Cognitive Therapy of Depression.* New York: Guilford.

Bjelland I, Dahl AA, Haug TT, Neckelmann D: The validity of the Hospital Anxiety and Depression Scale. An updated literature review. *Journal of Psychosomatic Research,* 52, 69-77.

Berrios, G. E., Ryley, J. P., & Garvey, T. P. (1988). Psychiatric morbidity in subjects with inner ear disease. *Clinical Otolaryngology,* 13, 259-266.

Billue, J. S. (1998). Subjective idiopathic tinnitus. *Clinical Excellence for Nurse Practitioners,* 2(2), 73-82.

Black, R. G. (1975). The chronic pain syndrome. *Surgical Clinics of North America,* 55, 999-1011.

Bolger, N., Delongis, A., Kessler, R. C. & Schilling, E. A. (1991). Effects of daily stress on negative mood. *Journal of Personality and Social Psychology,* 57(5), 808-818.

Bolger, N. & Schilling, E. A. (1991). Personality and the problems of everyday life – the role of neuroticism in exposure and reactivity to daily stressors. *Journal of Personality,* 59(3), 355-386.

Bonica, J. J. (1977). Neurophysiologic and pathophysiologic aspects of acute and chronic pain. *Archives of Surgery,* 112, 750-761.

Breakwell, G. & Wood, P. (2000). Diary techniques. In: Breakwell, G., Hammond, S., & Fife-Shaw, C. (Eds.), *Research methods in Psychology.* Sage Publications Ltd.

Bridges, K. &Goldberg, D. (1985). Somatic presentation of DSM-III psychiatric disorders in primary care. *Journal of Psychosomatic Research,* 29, 563-569.

Briner, W., Risey, J., Guth, P. & Norris, C. (1990). Use of the Million Clinical Multiaxial Inventory in evaluating patients with severe tinnitus. *American Journal of Otolaryngology*, 11, 334-337.

Broadbent, D. E. (1958). *Perception and communication*. London: Pergamon Press.

Broadbent, D. E. (1981). Effects of moderate levels of noise on human performance. In: Tobias, J. V., & Schubert, E. D. (Eds.) Hearing Research and therapy, Vol. 1. London: Academic Press.

Brown, D., Penny, J. E., Henley, C. M., Hodges, K. B., Kupetz, S. A., Gleen, D. W., and Jobe, P. C. (1981). Ototoxic drugs and noise. In D. Evered, & G. Lawrenson (eds.) *Tinnitus: CIBA Foundation Symposium 85* (pp. 151-171). London: Pitman Books.

Budd, R. J. & Pugh, R. (1995). The relationship between locus of control, tinnitus severity, and emotional distress in a group of tinnitus sufferers. *Journal of Psychosomatic Research*, 39, 1015-1018.

Burns, E. (1984). A comparison of variability among measurements of subjective tinnitus and objective stimuli. *Audiology*, 23, 426-440.

Bush, F. M. (1987). Tinnitus and otalgia in temporomandibular disorders. *Journal of Prosthetic Dentistry*, 58, 495-498.

Carlsson, S. G. & Erlandsson, S. I. (1991). Habituation and tinnitus: An experimental study. *Journal of Psychosomatic Research*, 35, 509-514.

Carayon, R. (1993). A longditudinal test of Karasek's job strain model amongst office workers. *Work and Stress*, 7(4), 299-314.

Ceranic, B. J., Prasher, D. K., & Luxon, L. M. (1995). Tinnitus and oto-acoustic omissions. *Clinial Otolaryngology*, 20, 192-200.

Chaturvedi, S. K., Chandra, P. S., Channabasa, S. M., Benna, M. B., & Pandian, R. D. (1994). Detection of anxiety and depression in cancer patients. *Nimhans Journal*, 12(2), 141-144.

Chollet, F., Loubinoux, I., Carel, C., Marque, P., Albucher, J. F., & Guiraud-Chaumeil, B. (1999). Mechanisms of motor recovery after cerebrovascular accident, *Revue Neurologique*, 155, 718-724.

Chronister, R. B., Hardy, S. G. P. (1997). The limbic system. In: Haines, D. E. (Ed.): *Fundamental Neuroscience*. Churchill Livingstone, New York, Edinburgh, London, pp. 443-454.

Chung, D. Y., Gannon, R. P. & Mason, K. (1984). Factors affecting the prevalence of tinnitus. *Audiology,* 23, 441-452.

Clough, P. J., & Earle, K. (2000). Mental Toughness: the concept and its measurement. In: Cockerill, I. (Ed.), *Soloutions in Sport Psychology.* Thomson.

Cohen, J., Cohen, P., West, S., & Aiken, L. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences.* 3rd Ed. Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, J. D., Perlstein, W. M., Braver, T. S., Nystrom, L. E., Noll, D. C., Jonides, J., & Smith, E. E. (1997). Temporal dynamics of brain activation during a working memory task. *Nature,* 386, 604-608.

Colding-Jørgensen, E., Lauritzen, M. Johnsen, N. J., Mikklesen, K. B., & Saermark, K. (1992). On the auditory-evoked magnetic P200 peak as an objective measure of tinnitus. In: Aran, J-M and Dauman, R. (Eds.), *Proceedings of the Fourth International Tinnitus Seminar, Bordeaux, France, 1991.* Kugler Publications, Amsterdam/New York. (pp. 323-326).

Coles, R. R. A., David, A. C. and Haggard, M. P. (1981). Epidemiology of tinnitus; In: Evered, D. and Laurenson, G. (Eds): *Tinnitus CIBA Foundation Symposium,* 85. London, Pitman, 16-34.

Coles, R. A. A., Smith, P. & Davies, A. (1990). The relationship between noise-induced hearing loss and tinnitus and its management. In: B. Burglund & T. Lindival (Eds.), *Noise as a Public Health Problem: Vol. 4, New Advances in Noise Research, part 1.* (pp. 87-112). Stockholm: Swedish Council for Building Research.

Coles, R. R. A. (1987). Tinnitus and its management. In: S. D. G. Stevens & A. G. Kerr (Eds.), *Scott-Brown's Otolaryngology.* Guilford: Butterwoth, 368-414.

Coles, R. R. A. (1997). Tinnitus. In: Stephens, D. (Ed.), *Adult Audiology,* Butterworth-Heinemann, Oxford, pp. 1-34.

Coles, R. R. & Baskill, J. L. (1996). Absolute loudness of tinnitus: tinnitus clinic data. In: G. E. Reich & J. A. Vernon (Eds.), *Proceedings of the Fifth International Tinnitus Seminar Bordeaux, 1991* (pp. 239-243). Amsterdam: Kugler.

Collet, L. (1987). Biofeedback and tension headaches: Prognostic utility of the MMPI. *Pain,* 29, 267-268.

Collet, L., Cottraux, J., Juenet, C. (1986). Tension headaches: Relation between MMPI paranoia score and pain and between MMPI hyhochondrasis score and frontalis EMG. *Headache,* 26, 365-368.

Collet, L., Moussu, M. F., Disant, F., Ahami, T. & Morgon, A. (1990). Minnesota Multiphasic Personality Inventory in tinnitus disorders. *Audiology,* 28, 101-106.

David, A. S., Woodruff, P. W., Howard, R., Mellers, J. D., Brammer, M., Bullmore, E., Wright, I., Andrew, C., & Williams, S. C. (1996). Auditory hallucinations inhibit exogenous activation of auditory association cortex. *Neuroreport,* 5, 2593-2597.

Davies, A. C. (1989). The prevalence of hearing impairment and reported hearing disability among adults in Great Britain. *International Journal of Epidemiology,* 18(4), 911-917.

Davies, A., McKenna, L., & Hallam, R. S. (1995). Relaxation and cognitive therapy in chronic tinnitus. *Psychological Health,* 10, 129-143.

Davies, A., & Rafaie, E. A. (2000). Epidemiology of tinnitus. In: Tyler, R.S. (Ed.), *Tinnitus Handbook.* San Diego: Singular Publishing Group, pp. 1-23.

Dineen, R., Doyle, J. & Bench, J. (1996). Audiological and psychological characteristics of a group of tinnitus sufferers, prior to tinnitus management training. *British Journal of Audiology,* 31, 27-38.

Dobie, R. A. (1999). A review of randomized controlled trials in tinnitus. *Laryngoscope,* 109, 1202-1211.

Dobie, R. A. & Sulivan, M. D. (1998). Antidepressant drugs and tinnitus. In: Vernon, J. (Ed.) *Tinnitus treatment and relief.* Boston: Allyn and Bacon, pp 43-51.

Duckert, L., & Rees, T. (1983). Treatment of tinnitus with intravenous lidocaine: A double-blind randomized trial. *Otolaryngology - Head and Neck Surgery,* 91, 550-555.

Earle, F. (2004). The construct of psychological fatigue: A psychometric and experimental analysis. Unpublished doctoral dissertation, University of Hull.

Easter, R. L. (April 2, 1997). *Tinnitus faq* [on-line]. Available May 2004: http://www.cccd.edu/faq/tinnitus.html

Eggermont, J. J. (2000). Physiological mechanisms and neural models. In: Tyler, R. S. (Ed.), *Tinnitus Handbook*. San Diego: Singular Publishing Group, pp. 125-148.

Elbert, T., Flor, H., Birbaumer, N., Knetch, S., Hampton, S., Larbig, W., & Taub, E. (1994). Extensive Reorganization of the somatosensaory cortex in adult humans after nervous system injury. *Neuroreport,* 5, 2593-2597.

Ellis, A. (1962). *Reason and emotion in psychotherapy*. New York: Lyle Stuart.

Erlandsson, S. I. (1990). *Tinnitus: tolerance or threat? Psychological and psychophysiological perspectives.* Unpublished Thesis, Department of Psychology, University of Goteborg, Goteborg, Sweden.

Erlandsson, S. I., Hallberg, L. R-M. & Axelsson, A. (1992). Psychological and audiological correlates to perceived tinnitus severity. *Audiology,* 31, 168-179.

Erlandsson, S. I., Rubinstein, B., Axelsson, A., & Carlsson, S. G. (1991). Psychological dimensions in patients with disabling tinnitus and craniomandibular disorders. *British Journal of Audiology,* 25, 15-24.

Erlandsson, S. I., Rubinstein, B., Carlsson, S. G., & Ringdahl, A. (1987a). Biofeedback and stomatognathic treatment - a prospective study of tinnitus patients. In: Feldmann, H. (Ed.). *Proceedings III International Tinnitus Seminar,* Harsch Verlag, Karlsruhe, 389-391.

Evans, E. F., Wilson, J. P., & Borerwe, T. (1981). Animal models of tinnitus. In: *CIBA Symposium 85,* pp. 108-129. Pitman Books Ltd: London.

Evans, M. G. 1985. A Monte Carlo Study of the Effects of Correlated Method Variance in Moderated Multiple Regression Analysis. *Organizational Behavior and Human Decision Processes,* 36, 305-323.

Faye K, Heng LH, Collomp R, Peroux E. (2003). Hypertension and stress. *Journal des maladies vasculaires,* 28 (1): 4-8.

Feldmann, H. (1971). Homolateral and contralateral masking of tinnitus by noisebands and by pure tones. *Audiology,* 10, 138-144.

Flor, H., Birbaumer, N., Braun, C., Elbert, T., Ross, B., & Hoke, M. (1995). Chronic pain enhances the magnitude of the magnetic-field evoked at the site of pain. *Journal of Psychophyiology,* 8 (3): 263-263.

Flor, H., Elbert, T., Knetch, S., Wienbruch, C., Pantev, C., Birbaumer, N., Larbig, W., & Taub, E. (1995). Phantom limb pain as a perpetual correlate of cortical reorganisation following an arm amputation. *Nature,* 375, 482-484.

Flor, H., & Turk, D. C. (1988). Chronic back pain and rheumatoid arthritis: Predicting pain and disability from cognitive variables. *Journal of Behavioural Medicine,* 11, 251-265.

Flowers K. A., & Robertson, C. (1985). The effect of Parkinsons Disease on the ability to maintain a mental set. *Journal of Neurosurgery and Psychiatry,* 48(6), 517-529.

Folmer, R. L., Griest, S. E., Meikle, M., & Martin, W. H. (1999). Tinnitus severity, loudness and depression. *Otolaryngology - Head and Neck Surgery,* 121 (1), 48-51.

Fordyce, W. E. (1976). *Behavioural modifications for chronic pain and illness.* St. Louis: Mosby.

Fowler, E. P. (1942). The "illusion of loudness" of tinnitus - its etiology and treatment. *Laryngoscope,* 52, 275-285.

Fowler, E. P. (1945) Control of head noises: Their illusion of loudness and timbre. *Archives of Otolaryngology,* 37, 391-398.

Frankenberg, F. R., & Hegarty, J. D. (1994). Tinnitus, psychosis, and suicide. *Archives of Internal Medicine,* 154, 2371.

Frith, C. (1996). The role of the prefrontal cortex in self-consciousness: the case of auditory hallucinations. *Philosophical Transactions of the Royal Society of London. Series B. Biological Sciences,* 351, 1505-1512.

Frith, C., & Dolan, R. J. (1997). Brain mechanisms associated with top-down processes in perception, *Philosophical Transactions of the Royal Society of London. Series B. Biological Sciences,* 352, 1221-1230.

Garron, D. C. & Leavitt, F. (1983). Chronic low back pain and depression. *Journal of Clinical Psychology,* 39, 487-493.

Gerber, K. E., Nehemkis, A. M. Charter, R. A., & Jones, H. C. (1985). Is tinnitus a psychological disorder? *International Journal of Psychiatry,* 15, 81-87.

Gerken, G. M. (1993). Alteration of central auditory processing of brief stimuli: a review and a neural model. *Journal of the Acoutical Society of America,* 93, 2038-2049.

Gervais, R. L. (2002). Patterns of work strain and well-being in nurses. Unpublished doctoral dissertation, University of Hull.

Giambra, L. M. & Quilter, R. E. (1988). Sustained attention in adulthood: A unique, large-sample, longitudinal and multicohort analysis using the Mackworth Clock Test. *Psychology and Aging,* 3, 75-83.

Gibson, E. (1971). Perceptual learning and the theory of word perception. *Cognitive Psychology,* 2, 351-368.

Goebel, G., Hiller, W., Fruhauf, K., Fichter, M. M. (1992a). Effects of inpatient multimodal behavioural treatment of complex chronic tinnitus: a controlled one year follow-up study. In: Aran, J-M., Dauman, R. (Eds.), *Tinnitus 91.* Amsterdam: Kugler Publications.

Goldstein, B., and Shulman, A. (1981). Tinnitus classification: medical audiologic assessment. *Journal of Laryngology and Otology,* 4, 33-38.

Goodwin, P. E. and Johnson, R. M. (1980). The loudness of tinnitus. *Acta Otolaryngology,* 90, 353-359.

Government Statistical Service OPCS Monitor. (1983). General Household Survey: The Prevalence of Tinnitus, 1981. GSH 83/1, 8th Feb, 1983.

Graham, J. (1981). Tinnitus in children with hearing loss. In: *CIBA Symposium 85: Tinnitus.* Pitman Books Ltd., London.

Graham, J. T., & Newby, H. A. (1962). Acoustical characteristics of tinnitus: Analysis. *Archives of Otolaryngology,* 75, 162-175.

Gray, W. C., Jastreboff, P. J., & Gold, S. L. (1996). Medical evaluation, diagnosis, and counselling of patients with tinnitus and hyperacusis. In: Reich, G. E. & Vernon, J. A. (Eds.), *Proceedings of the Fifth International Tinnitus Seminar, 1995.* Portland: American Tinnitus Association, 494-497.

Green, S. (1987). Habituation - attention and memory. In: *Physiological psychology: an introduction.* London: Routledge and Kegan Paul, 199-216.

Halford, J. B. S., & Anderson, S. D. (1991a). Tinnitus severity measured by a subjective scale, audiometry and clinical judgement. *Journal of Laryngology and Otology,* 105, 89-93.

Halford, J. B. S., & Anderson, S. D. (1991b). Anxiety and depression in tinnitus sufferers. *Journal of Psychosomatic Research,* 35, 383-390.

Hallberg, L. R. M. and Erlandsson, S. I. (1987) Tinnitus characteristics in tinnitus complainers and non-complainers. *British Journal of Audiology,* 27, 19-27.

Hallam, R. S. (1987) Psychological approaches to the evaluation and management of tinnitus distress; In: Hazell, J. W. P. (Ed.) *Tinnitus.* Edinburgh, Churchill Livingstone, 156-175.

Hallam, R. S., & Jakes, S. C. (1988). An evaluation of relaxation training in chronic tinnitus sufferers. In: Feldmann, H. (Ed.): *Proceedings of the Third International Tinnitus Seminar.* Karlsruhe: Harsch Verlag; pp.363-365.

Hallam, R. S., Jakes, S. C., Chambers, C. and Hinchcliffe, R. (1985). A comparison of different methods for assessing the 'Intensity' of tinnitus. *Acta Otolaryngology (Stockholm)*, 99, 501-508.

Hallam, R.S., Jakes, S. C. and Hinchcliffe, R. (1988). Cognitive variables in tinnitus annoyance. *British Journal of Clinical Psychology*, 27, 213-222.

Hallam, R., Rachman, S. and Hinchcliffe, R. (1984) Psychological aspects of tinnitus. In: Rachman, S. (Ed.): *Contribution to Medical Psychology.* Oxford, Pergamon Press, 32-53.

Hallam, R. S., & Stephens, S. D. G. (1985). Vestibular disorder and emotional distress. *Journal of Psychosomatic Research*, 29, 407-413.

Haralambous, G., Wilson, P. H., Platt-Hepworth, S., Tonkin, J. P., Henly, V. R., & Kavanagh, D. D. (1987). EMG biofeedback in the treatment of tinnitus: An experimental evaluation. *Behaviour Research and Therapy*, 25, 49-55.

Harrop-Griffiths, J., Katon, W., Dobie, R., Sakai, C. & Russo, J. (1987) Chronic tinnitus: association with psychiatric diagnosis. *Journal of Psychosomatic Research*, 31, 613-621.

Hazell, J. (1991). Tinnitus and disability with aging – adaptation and management. Acta Oto-Larynogica (Supplemental). 476, 202-208.

Hazell, J. W. P., Wood, S. M., Cooper, H., Stephens, S. D. G., Corcoran, A. L., Coles, R. R. A., Baskill, J. L., & Sheldrake, J. B. (1985). A clinical study of tinnitus maskers. *British Journal of Audiology*, 19, 65-116.

Henry, J. L. (1992). *Psychological management of tinnitus: An evaluation of cognitive interventions*. Unpublished doctoral dissertation, University of Sydney.

Henry, J. L. & Wilson, P. H. (1992). Psychological management of tinnitus. In: Aran, J-M., Dauman, R. (Eds.), *Tinnitus 91. Proceedings of the Fourth International Tinnitus Seminar.* Amsterdam: Kugler. pp. 477-480.

Henry, J. L., & Wilson, P. H. (1995). Coping with tinnitus: Two studies of psychological and audiological characteristics of patients with high and low tinnitus-related distress. *International Tinnitus Journal*, 1(2), 85-92.

Henry, J. L. & Wilson, P. H. (1996). The psychological management of tinnitus: A group treatment outcome study comparing the efficacy of a combined cognitive-educational programme with education only and a waiting list control. *International Tinnitus Journal*, 2, 1-12.

Herrmann C: International experiences with the Hospital Anxiety and Depression Scale--a review of validation data and clinical results. *Journal of Psychosomatic Research,* 42, 17-41.

Hockey, G. R. J. (1997). Compensatory control in the regulation of human performance under stress and high workload: A cognitive energetical framework. *Biological Psychology,* 45, 73-93.

Hockey, G. R. J. & Meijman, T. (1998). The construct of psychological fatigue: A theoretical and methodological analysis. Paper presented at the 3rd International Conference on Fatigue and Transportation, Australia.

Hollon, S. D. & Kendall, P. C. (1980). Cognitive self-statements in depression: Development of an Automatic Thoughts Questionnaire. *Cognitive Therapy and Research,* 4, 383-395.

House, P., Miller, L., & House, P. R. (1977). Severe tinnitus: treatment with biofeedback training. *Transactions - American Academy of Ophthalmology and Otolaryngology,* 84, 697-703.

House, P. R. (1981). Personality of the tinnitus patient. In: Evered, D. and Laurenson, G. (Eds.): Tinnitus CIBA Foundation Symposium 85. London: Pitman, 193-203.

House, P. R. (1991). Psychological Issues of Tinnitus. In: Schulman (Ed): Tinnitus: Diagnosis/Treatment. Philadelphia, Lea & Febiger, 533-537.

Ireland, C. E., Wilson, P. H., Tonkin, J. P. & Platt-Hepworth, S. (1985). An evaluation of relaxation training in the treatment of tinnitus. *Behaviour Research and Therapy,* 23, 423-430.

Jaccard, J., Turrisi, R., & Wan, C. (1990). Interaction Effects in Multiple Regression. Newbury Park, CA: Sage Publications, Inc.

Jacobson, G. P., Calder, J. A., Newman, C. W., Peterson, E. L., Wharton, J. A., & Ahmad, B. K. (1996). Electrophysiological indices of selective auditory attention in subjects with and without tinnitus. *Hearing Research,* 97, 66-74.

Jakes, S. C. (1997). Otological symptoms and emotional disturbance. In: Stephens, D. (Ed.), *Adult Audiology.* Butterworth-Heinemann, Oxford, pp 1-23.

Jakes, S. C., Hallam, R. S., Chambers, C., & Hinchcliffe, R. (1985). A factor analytical study of tinnitus complaint behaviour. *Audiology,* 24, 195-206.

Jakes, S. C., Hallam, R. S., McKenna, L., & Hinchcliffe, R. (1992). Group cognitive therapy for medical patients: An application to tinnitus. *Cognitive Therapy and Research,* 16, 67-82.

Jakes, S. C., Hallam, R. S., Rachman, S., & Hinchcliffe, R. (1986). The effects of reassurance, relaxation training and distraction on chronic tinnitus sufferers. *Behaviour Research and Therapy*, 24, 497-507.

Jastreboff, P. J. (1990). Phantom auditory perception (tinnitus): mechanisms of generation and perception. *Neuroscience Research*, 8, 221-254.

Jastreboff, P. J. (1995). Tinnitus as a phantom auditory perception: theories and clinical implications. In: Vernon J, Møller, A. R. (Eds.), *Mechanisms of Tinnitus*. Boston: Allyn & Bacon, 73-94.

Jastreboff, P. J. (1996). Clinical implication of the neurophysiological model of tinnitus. In: Reich, G., & Vernon, J. (Eds.), *Proceedings of the Fifth International Tinnitus Seminar*. Portland, Oregon: American Tinnitus Association.

Jastreboff, P. J., Brennan, J. F. and Sasaki, C. T. (1988). Phantom auditory sensations in rat: An animal model of tinnitus. *Behavioural Neuroscience*, 102, 811-822.

Jastreboff, P. J., Brennan, J. F., & Sasaki, C. T. (1991). Quinine-induced tinnitus in rats. *Archives of Otolaryngology - Head and Neck Surgery*, 117, 1162-1166.

Jastreboff, P. J., Gray, W. C., and Gold, S. L. (1996). Neurophysiological approach to tinnitus patients. *American Journal of Otolaryngology*, 17, 236-240.

Jastreboff, P. J., & Hazell, J. W. P. (1993). A neurophysiological approach to tinnitus: clinical implications. *British Journal of Audiology*, 1993, 27, 7-17.

Jastreboff, P. J., Hazell, J. W. P., & Graham, R. L. (1994). Neurophysiological model of tinnitus:dependence on the minimal masking level on treatment outcome. *Hearing Research*, 80, 216-232.

Jastreboff, P. J., Ikner, C. L. and Hassen, A. (1992). An approach to the objective evaluation of tinnitus in humans. In: Aran, J-M. & Dauman, R. (Eds.) *Tinnitus 91, Proceedings of the IV International Tinnitus Seminar* (pp. 331-339). Amsterdam: Kugler & Ghedini.

Jastreboff, P. J., & Sasaki, C. T. (1986). Salicylate-induced changes in spontaneous activity of single units in the inferior colliculus of the guinea pig. *Journal of the Acoustical Society*, 80, 1384-1391.

Jones, D. M., Macken, W. J., & Murray, A. C. (1993). Disruption of viual short-term memory by changing auditory stimuli – the role of segmentation. *Memory and Cognition*, 21(3), 318-328.

Kahneman, D. (1973). *Attention and Effort.* Prentice Hall, Englewood-Cliffs, New Jersey.

Kaltenbach, J. A. & McCaslin, D. L. (1996). Increases in spontaneous activity in the dorsal cochlear nucleus following exposure to high intensity sound: A possible neural correlate of tinnitus. *Auditory Neuroscience*, 3 (1): 57-78.

Keefe, F. J., Crisson, J., Urban, G. J., Williams, D. A. (1990). Analyzing chronic low back pain: The relative contribution of pain coping strategies. *Pain,* 40, 293-301.

Kemp, D. T. (1978). Stimulated acoustic emissions from within the human auditory system. *Journal of the Acoustical Society of America,* 64, 1386-1391.

Kemp, D. T. (1981). Physiologically active cochlear micromechanics - one source of tinnitus. In: D. Evered, & G. Lawrenson (Eds.) *Tinnitus: CIBA Foundation Symposium 85* (pp. 54-81). London: Pitman Books.

Kearney, B. G., Wilson, P. H., Haralambous, G. (1987). Stress appraisal and personality characteristics of headache patients: comparisons with tinnitus and normal control groups. *Behavioural Change,* 4, 25-32.

Keefe, F. J., Salley, A. N., & Lefebvre, J. C. (1992). Coping with pain: conceptual concerns and future directions. *Pain,* 51, 131-134.

Kendall, P. C., Hollon, S. D., Beck, A. T., Hamman, C. L., & Ingram, R. E. (1987). Issues and recommendations regarding use of the Beck Depression Inventory. *Cognitive Therapy Research,* 11, 289-299.

Kessler, R.C. (1987). The interplay of research design strategies and data analysis procedures in evaluating the effects of stress on health. In: Kasl, S.V. & Cooper, C.L. (Eds.), *Stress and health: Issues in research methodology.* Chichester: John Wiley & Sons.

Kiang, N. Y. S., Moxon, E. C., Levine, R. A. (1970). Auditory nerve activity in cats with normal and abnormal cochlea. In: Wolstenholme, G. E. W. & Knight, J. (Eds.) Sensorineural hearing loss. London: J & A Churchill, 1970: 241-249.

Kirch, C. A., Blanchard, E. B. & Parnes, S. M. (1989). Psychological characteristics of individuals high and low in their ability to cope with tinnitus. *Psychosomatic Medicine,* 51, 209-217.

Klockhoff, I., & Lindblom, U. (1967) Meniere's disease and hydrochlorthiazide: A critical analysis of symptoms and therapeutic effects. *Acta Otolaryngology*, 63, 347-365.

Kröner-Herwig, B. (ed.). (1997). *Psychologische Behandlung des chronischen Tinnitus [Psychological treatment of chronic tinnitus].* Weinham: Beltz.

Kröner-Herwig, B., Biesinger, E., Gerhards, F., Goebel, G., Greimel, K. V., & Hiller, W. (2000). Retraining therapy for chronic tinnitus: a critical analysis of its status. *Scandinavian Audiology,* 29, 67-78.

Kröner-Herwig, B., Hebing, G., Van Rijn-Kalkmann, U., Schilkowsky, G., & Esser, G. (1995). The management of chronic tinnitus - comparison of a cognitive-behavioural group training with yoga. *Journal of Psychosomatic Research,* 39, 153-165.

Krupp, L. B., LaRocca, N. G., Muir-Nash J., & Steinberg, A. D. (1989). Application to patients with multiple sclerosis and systemic lupus erthematosus. *Archives of Neurology,* 46, 1121-1123.

Kuk, F.K., Tyler, R. S., Rustad, N., Harker, L. A. & Tye-Murray, N. (1989) Alternating current at the eardrum for tinnitus reduction. *Journal of Speech and Hearing Research,* 32, 393-400.

Kuk, F. K., Tyler, R. S., Russel, D., & Jordan, H. (1990). The psychometric properties of a tinnitus handicap questionnaire. *Ear Hear,* 11, 434-445.

Landisbergis, P. (1988). Occupational Stress Among Health Care Workers: A Test of the Job Demands-Control Model. *Journal of Organizational Behavior* 9(3), 217-239.

Larsen, R. J. & Kasimatis, M. (1991). Day-to-day physical symptoms: Individual differences in the occurrence, duration, and emotional concomitants of minor daily illnesses. *Journal of Personality,* 59, 387-423.

Lechtenberg, R. & Schulman, A. (1984). The neurological implications on tinnitus. *Archives of Neurology,* 41, 718-721.

Lemaire, M. C., & Beutter, P. (1995). Brainstem auditory evoked responses in patients with tinnitus. *Audiology,* 34, 287-300.

Lepage, E. L. (1995). A model for cochlear origin of subjective tinnitus. In: Vernon, J. A. and Møller, A. R. (Eds.), Mechanisms of tinnitus. Allyn and Bacon, Boston, MA. pp. 115-147.

Lewis, J.E., Stephens, S. D., & Huws, D. (1992). Suicide in tinnitus sufferers. *Journal of Audiological Medicine,* 1, 30-37.

Lewis, J. E., Stephens, S. D. G., & McKenna, L. M. (1994). Tinnitus and suicide. *Clinical Otolaryngology,* 19, 50-54.

Lichstein, K. L., Riebel, B. W., & Richman, S. L. (2000). The Mackworth Clock Test: A computerized version. *Journal of Psychology*, 134(2), 153-161.

Lindberg, P., Lyttkens, L., Melin, L., & Scott, B. (1984). Tinnitus - incidence and handicap. *Scandinavian Audiology,* 13, 287-291.

Lindberg, P., Scott, B., Melin, L., & Lyttkens, L. (1987). Long-term effects of psychological treatment of tinnitus. *Scandinavian Audiology,* 16, 167-172.

Lindberg, P., Scott, B., Melin, L., & Lyttkens, L. (1988). Behavioural therapy in the clinical management of tinnitus. *British Journal of Audiology,* 22, 265-272.

Lockwood, A. H., Salvi, R.J., Coad, M. L., Towsley, M. L., Wack, D. S., & Murphy, M. S. (1998). The functional neuroanatomy of tinnitus; Evidence for limbic system links and neural plasticity. *Neurology,* 50, 114-120.

Lockwood, A. H., Wack, D. S., & Burkard, R. F. (2001). The functional anatomy of gaze-evoked tinnitus sustained lateral gaze, *Neurology,* 56, 472-480.

Love, A. (1987). Depression in chronic low back pain patients: Diagnostic efficacy of three self-report measures. *Journal of Clinical Psychology,* 43, 84-89.

Lutz, J. (1998). Sauerstoffbehandlungsmethoden - eine kritische Analyse etablierter und umstrittener Verfahren [Treatment by oxygenation: a critical analysis of well-established and controversial interventions]. *Versicherungsmedizin,* 50, 190-194.

Lynch, S. M. (2003). Cohort and life-course patterns in the relationship between education and health: A hierarchical approach. *Demography*, 40(2), 309-331.

Mackworth, N. H. (1948). The breakdown of vigilance during prolonged visual search. *Quarterly Journal of Experimental Psychology,* 1, 6-21.

Malone, J. R. L. & Hemsley, D. R. (1977). Lowered responsiveness and auditory signal detectability during depression. *Psychological Medicine,* 7, 717-722.

Manabe, Y., Yoshida, S., Saito, H., & Oka, H. (1997). Effects of lidocaine on salicyate-induced discharge of neurones in the inferior colliculus of the guinea pig, *Hearing Research,* 103, 192-198.

Marco, J. A. & Suls, J. (1993). Daily stress and the trajectory of mood – spillover, response assimilation, contrast, and chronic negative affectivity. *Journal of Personality and Social Psychology*, 64(6), 1053-1063.

Matthew, R. J. & Weinman, M. L. (1981). Physical symptoms of depression. *British Journal of Psychiatry,* 139, 293-296.

Matsuhira, T., & Yamashita, K. (1996). Factors contributing to tinnitus loudness. In: G. E. Reich and J. A. Vernon (Eds.), *Proceedings of the Fifth International Tinnitus Seminar, Portland, 1995* (pp. 171-175). Portland: American Tinnitus Association.

Matsuhira, T., Yamashita, K., & Yasuda, M. (1992). Estimation of the loudness of tinnitus from matching tests. *British Journal of Audiology,* 26, 387-395.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, 109, 163-203.

McFadden, D. (1982). *Tinnitus: Facts, theories and treatments.* Working Group 89, National Research Council. Washington DC: Academic Press.

McKenna, L. (1997). Psychological treatments for tinnitus. In: Vernon, J.A. (Ed.): *Tinnitus Treatment and Relief.* Allyn and Bacon: Boston MA, pp. 140-155.

McKenna L, Hallam RS, Shurlock L. Cognitive functioning in tinnitus patients. In: Reich GE, Vernon JA, (Eds.), *Proceedings of the fifth International Tinnitus Seminar 1995.* Portland: American Tinnitus Association; 1996. p. 589-95.

McKinney, C. J., Hazell, J. W. P., & Graham, R.L. (1999) An evaluation of the TRT method. In: Hazell, J. W. P. (Ed.), *Proceedings of the Sixth International Tinnitus Seminar, Cambridge, UK.* British Society of Audiology, pp. 99-105.

Meikle, M. B. and Griest, S. E. (1987). Gender-based differences in characteristics of tinnitus. *Hearing Journal,* 42, 68-76.

Meikle, M. B. and Griest, S. E. (1991). Computer data analysis: Tinnitus data registry. In Schulman A. (Ed.): *Tinnitus: Diagnosis/Treatment.* Philadelphia, Lea & Febiger, 416-430.

Meikle, M. B. and Taylor-Walsh, E. (1984) Characteristics of tinnitus and related observations in over 1,800 tinnitus clinic patients: Proceedings of the 2nd International Tinnitus Seminar. *Journal of Laryngology and Otology,* 9, 17-21.

Meikle, M. B., Vernon, J. & Johnson, R. M. (1984). The perceived severity of tinnitus. *Otolaryngology, Head and Neck Surgery,* 922, 689-696.

Melzack, R., & Melinkoff, D. F. (1974). Analgesia produced by brain stimulation: evidence for a prolonged onset period. *Experimental Neurology*, 43, 369-374.

Melzack, R. and Wall, P. D. (1965). Pain mechanisms: A new theory. *Science,* 150, 971-979.

Meric, C., Gartner, M., Collet, L. and Chery-Croze, S. (1998). Psychopathological profile of tinnitus sufferers: evidence concerning the relationship between tinnitus features and impact on life. *Audiology and Neuro-otology,* 3, 240-252.

Mihail, R. C., Crowley, J. M., & Welden, B. E. (1988). The tricyclic trinipramine in the treatment of subjective tinnitus. *Annals of Otology, Rhinology and Laryngology,* 97, 120-123.

Mills, S. E. (1980). Amitriptyline side effect. *New Zealand Medical Journal,* 92, 66-67.

Mirz, F., Pedersen, C. B., Ishizu, K., Johannsen, P., Ovesen, T., Stødkilde-Jøgensen, H., & Gjedde, A. (1999). Positron emission tomography of cortical centers of tinnitus. *Hearing Research,* 134, 133-144.

Mizuochi, T. (1954). A study on the relationship of hearing threshold and tinnitus aurium. *Otolaryngology (Toyko),* 26, 105-108.

Møller, A. R. (1997). Similarities between chronic pain and tinnitus. *American Journal of Otology,* 18, 577-585.

Møller, A. R., Jannetta, P. J., & Jho, H. D. (1992). Compound action potentials recorded from the exposed eighth nerve in patients with intractable tinnitus. *Laryngoscope,* 102, 187-197.

Monk, T. H., Buysse, D. J., Reynolds, C. F. III, Jarrett, D. B., & Kupfer, D. J. (1992). Rhythmic vs. homeostatic influences on mood, activation, and performance in young and old men. *Journal of Gerontology: Psychological Sciences,* 47, 221-227.

Morgan, D. H. (1975). Surgical correction of temporomandibular joint arthritis. *Journal of Psychosomatic Research,* 31, 499-511.

Morris, J. H., Sherman, J. D., & Mansfield, E. R. (1986). Failures to detect moderating effects with ordinary least squares-moderated multiple regression: Some reasons and a remedy. *Psychological Bulletin, 99,* 282-288.

Mühlnickel, W., Elbert, T., Taub, E., & Flor, H. (1998). Reorganization of auditory cortex in tinnitus. *Proceedings of the National Academy of Science (USA),* 95, 10340-10343.

Newman, C., Wharton, J., & Jacobsen, G. (1997). Self-focused attention in patients with tinnitus. *Journal of the American Academy of Audiology,* 8, 143-149.

Nicholas, M. K., Wilson, P. H. & Goyen, J. (1991). An evaluation of cognitive and behavioural treatments for chronic low back pain, with and without relaxation training. *Behaviour Research and Therapy,* 29, 225-238.

Nicholas, M. K., Wilson, P. H. & Goyen, J. (1992). Comparison of cognitive-behavioural group treatment and an alternative, non-psychological treatment for chronic low back pain. *Pain,* 48, 339-347.

North, T. C., McCullagh, P., & Vu Tran, Z. (1990). Effect of exercise on depression. *Exercise and Sports Sciences Reviews*, 18, 379-415.

Norton, S. J., Schimdt, A. R. & Stover, L. J. (1990). Tinnitus and otoacoustic emissions: Is there a link? *Ear and hearing,* 11, 159-166.

O'Conner, S., Hawthorne, M., Britten, S. R. & Webber, P. (1987) Identification of psychiatric morbidity in a population of tinnitus sufferers. *Journal of Laryngology and Otology,* 101, 791-794.

Pantev, C., Hoke, M., Lutkenhoner, B., Lehnertz, K. & Krumpf, W. (1989). Tinnitus remission objectified by neuromagnetic measurements. *Hearing Research,* 40, 261-264.

Pedhazur, E. (1982). *Multiple regression in behavioural research.* New York: Holt, Rinehart & Winston.

Penner, M. J. (1983b). The annoyance of tinnitus and the noise required to mask it. *Journal of Speech and Hearing Research,* 26, 73-76.

Penner, M. J. (1984). Equal loudness contours using subjective tinnitus as the standard. *Journal of Speech and Hearing Research,* 27, 267-274.

Penner, M. J. (1986). Magnitude estimation and the "paradoxical" loudness of tinnitus. *Journal of Speech and Hearing Research,* 29, 407-412.

Penner, M. J. (1988). Judgements of the loudness of tinnitus before and after masking. *Journal of Speech and Hearing Research,* 31, 582-587.

Penner, M. J. (1989). Empirical tests demonstrating two coexisting sources of tinnitus: A case study. *Journal of Speech and Hearing Research,* 32, 458-462.

Penner, M. J. (1990). An estimate of the prevalence of tinnitus caused by spontaneous otoacoustical emissions. *Archives of Otolaryngology - Head and Neck Surgery,* 116, 418-423.

Penner, M. J. & Burns, E. M. (1987). The dissociation of SOAEs and tinnitus. *Journal of Speech and Hearing Research,* 30, 396-403.

Persson, L. O. & Sjoberg, L. (1987). Mood and somatic symptoms. *Journal of Psychosomatic Research,* 31, 499-511.

Posner, M. I., Petersen, S. E., Fox, P. T., & Raichle, M. E. (1988). Localization of cognitive operations in the human brain. *Science,* 240, 1627-1631.

Puel, J-L.,Bobbin, R. P., & Fallon, M. (1990). Salicyate, mefenamate, mecogenamate, and quinine on cochlear potentials. *Otolaryngology, Head and Neck Surgery,* 102, 66-73.

Pugh, K. R., Shaywitz, B. A., Shaywitz, S. E., Fulbright, R. K., Byrd,. D., Skudlarski, P., Shankweiler, D. P., Katz, L., Constable, R. T., Fletcher, J., Larcadie, C., Marchione, K., & Gore, J. C. (1996). Auditory selective attention: an fMRI investigation. *Neuroimage*, 4, 159-173.

Putz, V. R. (1975). The effects of different modes of supervision on vigilance behaviour. *British Journal of Psychology*, 66, 157-160.

Putz, V. R., & Rothe, R. (1974). Peripheral signal detection and concurrent compensatory tracking. *Journal of Motor Behavior*, 6, 155-163.

Rajan, R., Irvine, D. R., Wise, L. Z., & Heil, P. (1993). Effect of unilateral partial cochlear lesions in adult cats on the representation of lesioned and unlesioned cochleas in primary auditory cortex. *Journal of Comparative Neurology,* 338(1), 17-49.

Recanzone, G. H., Schreiner, C. E., & Merzenich, M. M. (1993). Plasticity in the frequency representation of primary auditory cortex following discrimination training in adult owl monkeys. *Journal of Neuroscience,* 13, 87-103.

Reed, G., F. (1960). An audiometric study of two hundred cases of subjective tinnitus. *Archives of Otolaryngology,* 71, 94-104.

Reich, G. E. and Johnston, R. M. (1984). Personality characteristics of tinnitus patients. *Journal of Laryngology and Otology,* 9, 228-232.

Rizzardo, R., Savastano, M., Maron, M. B., Mangialaio, M., & Salvadori, L. (1998). Psychological distress in tinnitus patients. *The Journal of Otolaryngology,* 27, 21-25.

Romand, R. (1992). Neurotransmitters of the central auditory system and physiopharmacological origin of tinnitus. In: Aran, J-M. and Daumenm R. (Eds.), *Proceedings IV International Tinnitus Seminar (1991).* Bordeaux, France, Kugler Publications, Amsterdam/New York, pp. 181-193.

Ross, V., Echevarria, K. H., & Robinson, B. (1991). Geriatric tinnitus: causes, clinical treatment, and prevention. *Journal of Geronological Nursing*, 17(10), 71-76.

Roten, D. (1982). Fatigue and the post surgical patient. In: Norris M. C. (Ed), *Concept clarification in nursing*. Rockville, MD: Aspen Systems Corp.

Rubinstein, B. and Carlsson, G. E. (1987). Effects of stomatognathic treatment on tinnitus: A retrospective study. *The Journal of Craniomandibular Practice,* 5, 254-259.

Rubinstein, B. & Erlandsson, S. I. (1991). A stomatognathic analysis of patients with disabling tinnitus and craniomandibular disorders (CMD). *British Journal of Audiology,* 25, 77-83.

Rudy, T. E., Kerns, R. D., & Turk, D. C. (1988). Chronic pain and depression: Toward a cognitive-behavioural mediation model. *Pain,* 35, 129-140.

Rybak, L. P. (1986). Drug ototoxicity. *Annual Review of Pharmacological Toxicology,* 26, 79-99.

Sakai, C. T., Kauer, J. S. & Babitz, L. (1980). Differential (14C)2-deoxyglucose uptake after deafferentation of the mammal in auditory pathway - A model for examining tinnitus. *Brain Research,* 194, 511-516.

Sakai, M., Sato, M., Iida, M., Ogata, T., Ishida, K. (1995). The effect of tinnitus on stapes surgery for otosclerosis. Reviews of Laryngology, Otology and Rhinology, 116, 27-30.

Salvi, R. J., Lockwood, A. H., & Burkard, R. (2000). Neural plasticity and tinnitus. In: Tyler, R. S. (Ed.), *Tinnitus Handbook.* San Diego: Singular Publishing Group, pp 125-148.

Sataloff, J., Sataloff, R. T., & Lueneburg, W. (1987). Tinnitus and vertigo in healthy senior citizens without a history of noise exposure. *American Journal of Otolaryngology,* 8, 87-89.

Scott, B., Lindberg, P., Melin, L. & Lyttkens, L. (1985). Psychologial treatment of tinnitus: An experimental group study. *Scandinavian Audiology,* 14, 223-230.

Shacham, S., Reinhardt, L. C., Raubertas, R. F. & Cleeland, C. S. (1983). Emotional states and pain: Intra-individual and inter-individual measures of association. *Journal of Behavioural Medicine,* 6, 405-419.

Schreiner, C. E. & Snyder, R. L. (1987). A physiological animal model of peripheral tinnitus. In: H. Feldmann (Ed.) *Proceedings of the III International Tinnitus Seminar* (pp. 100-106). Karlsruhe, West Germany: Harsch Verlag.

Seidman, M. D., & Jacobson, G. P. (1996). Update on tinnitus. *Otolaryngologic Clinics of North America,* 29, 455-465.

Settle, E. C. (1991). Tinnitus related to bupropion treatment. *Journal of Clinical Psychiatry,* 52, 352.

Sheldrake, J. B., Jastreboff, P. J., & Hazell, J. W. P. (1996). Perspectives for total elimination of tinnitus perception. In: Reich, G. E. & Vernon, J. (Eds.): *Proceedings of the Fifth International Tinnitus Seminar 1995.* Portland: American Tinnitus Association, pp. 531-536.

Sheldrake, J. B., Wood, S. M. and Cooper, H. R. (1985). Practical aspects of the instrumental management of tinnitus. *British Journal of Audiology,* 19, 147-150.

Shiomi, Y., Nagamine, T., Fuijiki, N., Hirano, S., Naito, Y., Shibasaki, H., & Honjo, I. (1997). Tinnitus remission by lidocaine demonstrated by auditory-evoked magnetoenchpalogram. A preliminary report. *Acto Otolaryngology (Stockh),* 117, 31-34.

Shulman, A. (1991). Epidemiology of tinnitus. In: A. Shulman (Ed.), *Tinnitus: Diagnosis/treatment* (pp. 248-252). Philadelphia: Lea & Febiger.

Shulman, A., and Goldstein, B. (1987). *Proceedings of the III International Tinnitus Seminar* (pp. 251-256). Karlsruhe, West Germany: Harsch Verlag.

Shulman, A., Strashun, A. M., Afriyie, M., Aronson, F., Abel, W., & Goldstein, B. (1995). *International Tinnitus Journal,* 1, 13-29.

Shulman, A., Tonndorf, J., & Goldstein, B. (1985). Electrical tinnitus control. *Acta-Otolaryngology,* 99, 318-325.

Sininger, S., Eggermont, J. J. & King, A. J. (1992). Spontaneous activity from the peripheral auditory system in tinnitus. In: J-M. Aran & R. Dauman (Eds.) *Tinnitus 91. Proceedings of the IV International Tinnitus Seminar* (p. 342-345). Amsterdam: Kugler & Ghedini.

Smets, E. M. A., Garssen, B., Bionke, B., & De Haes, J. C. (1995). The multidimensional fatigue inventory (MFI): Psychometric qualities of an instrument to assess fatigue. *Journal of Psychosomatic Research,* 39(5), 315-325.

Smith, T. W., Peck, J. R., Milano, R. A., & Ward, J. R. (1988). Cognitive distortion in rheumatoid arthritis: Relation to depression and disability. *Journal of Consulting and Clinical Psychology,* 56, 412-416.

Sokolov, Y. (1963). *Perception and the conditioned reflex.* Oxford: Pergamon Press.

Spanswick, C. C., & Main, C. J. (1989). The role of the anaesthetist in the management of chronic low back pain patients. In: M. Roland & J. Jenner (Eds.), *Back pain: New approaches to education and rehabilitation* (108-128). Manchester: Manchester University Press.

Stephens, S. D. G. & Corcoran, A. L. (1985). A controlled study of tinnitus masking. *British Journal of Audiology,* 19, 159-167.

Stephens, S. D. G. & Hallam, R. S. (1985). The Crown-Crisp experimental index in patients complaining of tinnitus. *British Journal of Audiology,* 19, 151-158.

Stouffer, J. L. & Tyler, R. S. (1990). Characterisation of tinnitus by tinnitus patients. *Journal of Speech and Hearing Disorders,* 55, 439-453.

Stroop, J.R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 28,* 643-662

Sweetow, R. W. (1984). Cognitive-behavioural modification in tinnitus management. *Hearing Instruments,* 35(9), 14-18.

Sweetow, R. W. (1986). Cognitive aspects of tinnitus patient management. *Ear and Hearing,* 7(6), 390-396.

Sullivan, M. D., Katon, W., Dobie, R., Sakai, C., Russo, J & Harrop-Griffiths, J. (1988). Disabling tinnitus. Association with affective disorder. *General Hospital Psychiatry,* 10, 285-291.

Szechtman, H., Woody, E., Bowers, K. S., & Nahmais, C. (1998). Where the image appears real: a positron emission tomography study of auditory hallucinations. *Proceedings of the National Academy of Sciences USA,* 95, 1956-1960.

Taylor, H. & Curran, N. M. (1985). *The Nuprin pain report.* New York: Louis Harris.

Tennen, H., Suls, J., & Affleck, G. (1991). Personality and daily experience – the promise and the challenge. *Journal of Personality,* 59(3), 313-337.

Thomas, L. T. (Ed), (1993). *Tabers' cyclopedic medical dictionary* (17th ed.). Philadelphia: Lea & Febiger.

Tonndorf, J. (1987). The analogy between tinnitus and pain: A suggestion for a physiological basis of chronic tinnitus. *Hearing Research,* 28, 271-275.

Turk, D. C. & Rudy, T. E. (1986). Assessment of cognitive factors in chronic pain: A worthwhile enterprise? *Journal of Consulting and Clinical Psychology,* 56, 261-266.

Tyler, R. S. (1992). The psychophysical measurement of tinnitus. In: Aran, J. M. and Dauman, R. (Eds.): Tinnitus 91. Amsterdam, Kugler, 17-25.

Tyler, R. S., Aran, J-M., & Dauman, R. (1992). Recent advances in tinnitus. *American Journal of Audiology,* 1, 36-44.

Tyler, R. S. & Baker, L. J. (1983). Difficulties experienced by tinnitus sufferers. *Journal of Speech and Hearing Disorders,* 48, 150-154.

Tyler, R. S. & Conrad-Armes, D. (1983). The determination of tinnitus loudness considering the effects of recruitment. *Journal of Speech and Hearing Research,* 26, 59-72.

Tyler, R. S. & Kelsay, D. (1990) Advantages and disadvantages perceived by some of the better cochlear-implant patients. *American Journal of Otolaryngology,* 11(4), 282-289.

Tyler, R. S. & Stouffler, J. L. (1989). A review of tinnitus loudness. *The Hearing Journal,* 42(11), 52-57.

Tzuro, N., Massioui, F. E., Crivello, F., Joliot, M., Renault, B., & Mazoyer, B. (1997). Functional anatomy of human auditory attention studied with PET. *Neuroimage,* 5, 63-77.

Vanleeuwen, J. P., Meijer, E., Braspenning, J. C., & Cremers, C. (1996). Quality of life after acoustic neuroma surgery, *Annuals of Otolarynology,* 105, 423-430.

Vernon, J. (1976). The loudness of tinnitus. *Hear, Speech, Action,* 44, 17-19.

Vernon, J. (1977). Attempts to relieve tinnitus. *Journal of the American Auditory Society,* 2, 124-131.

Vernon, J. (1978). Information from U.O.H.S.C. Tinnitus Centre. *American Institute Association Newsletter,* 3, 1-4.

Vernon, J. (1991). Common errors in the use of masking for relief of tinnitus. In: A. Shulman (Ed.), *Tinnitus: Diagnosis/treatment* (pp. 50-66). Philadelphia: Lea & Febiger.

Vernon, J. (1992). Tinnitus: Causes, evaluation and treatment. In: English G. M. (Ed.), *Otolaryngology.* Philidelphia, Lipincott, 1-25.

Vernon, J. (1998). *Tinnitus: Treatment and Relief.* Allyn & Bacon: Boston.

Vernon, J., Griest, S., & Press, L. (1990). Attributes of tinnitus and the acceptance of masking. *American Journal of Otolaryngology,* 11, 44-50.

Vernon, J. & Meikle, M. B. (1985). Clinical Insights into possible physiological mechanisms of tinnitus. In: Myers, E. (Ed.). *New Dimensions in Otorhino-laryngology - Head and Neck Surgery,* Vol. 1, Elsevier Science Publishers, B. V., Amsterdam, 439-446.

Vesterager, V. (1994). Combined psychological and prosthetic management of tinnitus in a cross-sectional study of patients with severe tinnitus. *British Journal of Audiology,* 28, 1-11.

Volinn, E., Lai, D., McKinney, S., & Loeser, J. D. (1988). When back pain becomes disabling: A regional analysis. *Pain,* 46, 185-194.

Von Knorring, L. (1965). The experience of pain in depressed patients. *Neuropsychobiology,* 1, 155-165.

Wadell, G., Bircher, M., Finlayson, D., & Main, C. J. (1984). Symptoms and signs: Physical illness or illness behaviour? *British Medical Journal,* 289, 739-741.

Wallhäusser-Franke, E. (1997). Salicyate evokes c-fos expression in the brain stem: implications for tinnitus. *Neuroreport,* 8, 725-728.

Wallhäusser-Franke, E., Braun, S., & Langer, G. (1996). Salicyate alters 2-DG uptake in the auditory system: a model for tinnitus? *Neuroreport,* 7, 1585-1588.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measuresof positive and negative affect – the PANAS scales. *Journal of Personality and Social Psychology,* 54(6), 1063-1070.

Watura, R., & Vetter, N. J. (1991). Mental illness and distress. In Crompton, G. (ed.) *The Health of South Glamorgan - the annual report of the director of public medicine,* South Glamorgan Health Authority, Cardiff, UK. pp. 21-24.

Waxmen, H. M., McCreary, G., & Weinret, R.M. (1985). A comparison of somatic complaints among depressed and non-depressed older persons. *Gerontologist,* 25, 501-507.

Weir, C. C., Pasanen, E. G., & McFadden, D. (1988). Partial disassociation of spontaneous otoacoustic emissions and distortion products during aspirin use in humans. *Journal of the Acoustical Society of America,* 84, 230-237.

Wickens, C.D. (1984). Processing resources in attention. In: R. Parasuraman & D.R. Davies (Eds.), *Varieties of Attention.* New York: Academic Press.

Wickens, C.D. (1991). Processing resources and attention. In: D.L. Damos (Ed.), *Multiple-Task Performance.* London: Taylor & Francis.

Wickens & Hollands (2000). *Engineering Psychology and Human Performance.* Prentice Hall.

Willott, J. F., Aitken, L. M., & McFadden S. L. (1993). Plasticity of auditory cortex associated with sensorineural hearing loss in adult C57BL/6J mice. *Journal of Comparative Neurology,* 329(3), 402-411.

Wilson, P. H., & Henry, J. (1992). *Tinnitus Cognitions Questionnaire: Psychometric properties of a scale designed to assess engagement in positive and negative thinking about tinnitus.* Unpublished manuscript.

Wilson, P. H., & Henry, J. (1998). Tinnitus Cognitions Questionnaire: Development and Psychometric Properties of a Measure of Dysfunctional Cognitions Associated with Tinnitus. *International Tinnitus Journal,* 4(1), 23-30.

Wilson, P. H., Henry, J., Bowen, M. & Haralambos, G. (1991) Tinnitus reaction questionnaire: Psychometric properties of a measure of distress associated with tinnitus. *Journal of Speech and Hearing Research,* 34, 197-200.

Wilson P. H., Henry, J., Anderson, G., Lindberg, P., & Hallam, R. S. (1998). A critical analysis of directive counselling as a component of tinnitus retraining therapy. *British Journal of Audiology,* 32, 273-286.

Wilson, P. H., Henry, J. L., & Nicholas, M. K. (1993). Cognitive methods in the management of chronic pain and tinnitus. *Australian Psychologist,* 28(3), 172-180.

Wise, K., Rief, W., & Goebel, G. (1998). Meeting the expectations of chronic tinnitus patients: Comparison of a structured group therapy program for tinnitus management with a problem-solving group. *Journal of Psychosomatic Research,* 44, 681-685.

Woodruff, P. W., Wright, I.C., Bullmore, E. T., Brammer, M., Howard, R. J., Williams, S. C., Shapleske, J., Rossell, S., David, A. S., McGuire, P. K., & Murray, R. M. (1997). Auditory hallucinations and the temporal cortical response to speech in schizophrenia: a functional magnetic resonance imaging study. *American Journal of Psychiatry,* 154, 1676-1682.

Zatorre, R. J., Evans, A. C., Meyer, E., & Gjedde, A. (1992). Lateralization of phonetic and pitch discrimination in speech processing. *Science,* 256, 846-849.

Zatorre, R. J., Halpern, A. R., Perry, D. W., Meyer, E., & Evans, A. C. (1996). Hearing in the mind's ear: a PET investigation of musical imagery and perception. *Journal of Cognitive Neuroscience,* 8, 26-46.

Zatorre, R. J., & Samson, S. (1991). Role of right temporal neocortex in retention of phonetic and pitch in auditory short-term memory. *Brain,* 114, 1908-1919.

Zenner, H. P. & Ernst, A. (1993). Cochlear-motor, transduction and signal-transfer tinnitus: models for three types of cochlear tinnitus. *European Archives of Otorhinolaryngology,* 249, 447- 454.

Zigmond AS, Snaith RP. The Hospital Anxiety and Depression. Scale. Acta Psychiatrica Scandinavia, 67: 361-370.

Zorilla L. T., Aguirre, G. K., Zarahn, E., Cannon, T. D., D'Esposito, M. (1996). Activation of the prefrontal cortex during judgements of recency: a functional MRI study. *Neuroreport,* 7, 2803-2806.

Thank you for agreeing to participate in this experiment. Firstly, I would like to emphasise just how grateful I am for you agreeing to give up your time to assist in my research. It is appreciated.

In order to continue you must first be aware of the rights you hold as a participant. Because this study will include feedback - and because you may be requested to take part in future research - the data that you provide will not be entirely anonymous. It will however be confidential. No one else other than myself - James Jackson - will have access to any information that can be traced back to you at a later date. Also, if you feel the need, you have the right to withdraw from this experiment at any point before it is completed.

The experiment will last roughly 60 minutes, though this will differ for individual participants. It will consist of both questionnaires and a series of tasks for you to perform. If this set-up is acceptable to you, please fill in your details below and inform the experimenter that you are ready to begin.

Name (please print): ______________________________

Age: ______ Gender (M/F): ______

Contact address: ______________________________

______________________________

______________________________

E-mail address (if applicable): ________________________

Signature:

Please answer the following questions as quickly and as speedily as possible. There is no need to take too much time, as your first instinct is probably the most accurate one.

| | *Please circle the correct response* | |
|---|---|---|
| Does your tinnitus make it difficult for you to concentrate? | Yes | No |
| Are you almost always aware of your tinnitus? | Yes | No |
| Do you find that your tinnitus bothers you when you are doing something physical, such as dressing or gardening? | Yes | No |
| Does your tinnitus cause you problems in getting off to sleep? | Yes | No |
| Would you say that generally, your tinnitus does not bother you? | Yes | No |
| Do you sometimes go for hours without noticing your tinnitus? | Yes | No |
| Is your tinnitus very noisy? | Yes | No |
| Does your tinnitus frequently upset you? | Yes | No |
| Do you often have a day or more completely free of tinnitus? | Yes | No |

Please turn over

Continue to answer the following questions as quickly and as speedily as possible. There is no need to take too much time, as your first instinct is probably the most accurate one.

| | *Please circle the correct response* | |
|---|---|---|
| When you are busy, do you quite often forget about your tinnitus? | Yes | No |
| Is your tinnitus present for at least part of every day? | Yes | No |
| Does your tinnitus often interfere with your ability to relax? | Yes | No |
| Would you say that although your tinnitus can be irritating, it does not get you down? | Yes | No |
| Do you often talk about the problems your tinnitus causes to others? | Yes | No |
| Is it unusual for your tinnitus to annoy you when you are trying to read or watch television? | Yes | No |
| Would you say that you would have a much more enjoyable life if you did not have tinnitus? | Yes | No |

Please turn over.

(1)

Below is a set of statements that describes a range of feelings. Please indicate to what extent you agree with each statement - **considering how you feel right now**.

*1 = strongly disagree*
*5 = strongly agree*

| | Please circle <-disagree agree-> | | | | |
|---|---|---|---|---|---|
| I feel mentally tired | 1 | 2 | 3 | 4 | 5 |
| I feel bored | 1 | 2 | 3 | 4 | 5 |
| I feel somewhat sleepy | 1 | 2 | 3 | 4 | 5 |
| I feel detached/uninterested | 1 | 2 | 3 | 4 | 5 |
| I don't feel like making much of an effort | 1 | 2 | 3 | 4 | 5 |
| I feel like closing my eyes and having a nap | 1 | 2 | 3 | 4 | 5 |
| I feel alert and focused | 1 | 2 | 3 | 4 | 5 |
| I feel worn out physically | 1 | 2 | 3 | 4 | 5 |
| I feel uneasy | 1 | 2 | 3 | 4 | 5 |
| I feel unable to continue | 1 | 2 | 3 | 4 | 5 |
| I feel tense/on edge | 1 | 2 | 3 | 4 | 5 |
| I feel irritated and annoyed | 1 | 2 | 3 | 4 | 5 |
| I feel wide awake | 1 | 2 | 3 | 4 | 5 |
| I feel mentally drained | 1 | 2 | 3 | 4 | 5 |
| I feel physically tired | 1 | 2 | 3 | 4 | 5 |
| I feel drowsy | 1 | 2 | 3 | 4 | 5 |
| I feel lively and energetic | 1 | 2 | 3 | 4 | 5 |
| I feel a bit frustrated | 1 | 2 | 3 | 4 | 5 |

Thank you.

(2)

**Below is a set of statements that describes a range of feelings. Please indicate to what extent you agree with each statement – considering how you feel right now.**

*1 = strongly disagree*
*5 = strongly agree*

| | Please circle <-disagree | | | | agree-> |
|---|---|---|---|---|---|
| I feel mentally tired | 1 | 2 | 3 | 4 | 5 |
| I feel bored | 1 | 2 | 3 | 4 | 5 |
| I feel somewhat sleepy | 1 | 2 | 3 | 4 | 5 |
| I feel detached/uninterested | 1 | 2 | 3 | 4 | 5 |
| I don't feel like making much of an effort | 1 | 2 | 3 | 4 | 5 |
| I feel like closing my eyes and having a nap | 1 | 2 | 3 | 4 | 5 |
| I feel alert and focused | 1 | 2 | 3 | 4 | 5 |
| I feel worn out physically | 1 | 2 | 3 | 4 | 5 |
| I feel uneasy | 1 | 2 | 3 | 4 | 5 |
| I feel unable to continue | 1 | 2 | 3 | 4 | 5 |
| I feel tense/on edge | 1 | 2 | 3 | 4 | 5 |
| I feel irritated and annoyed | 1 | 2 | 3 | 4 | 5 |
| I feel wide awake | 1 | 2 | 3 | 4 | 5 |
| I feel mentally drained | 1 | 2 | 3 | 4 | 5 |
| I feel physically tired | 1 | 2 | 3 | 4 | 5 |
| I feel drowsy | 1 | 2 | 3 | 4 | 5 |
| I feel lively and energetic | 1 | 2 | 3 | 4 | 5 |
| I feel a bit frustrated | 1 | 2 | 3 | 4 | 5 |

Thank you.

In order to allow for the complexities of modern life, the rest of these questionnaires can be completed at your convenience. However, it is in the interest of the experimenter that a couple of points are raised.

**If you are a participant in the tinnitus group:**

Tinnitus is a changeable condition, one that varies over time. As such, the aspects of the study that you have already completed will have a greater relationship with these further questionnaires if they are completed quickly.

**In general:**

The answers to questionnaires are also affected by time. While it is not a problem for you to take a break in-between questionnaires, it *will* affect the study if you take a break halfway through a questionnaire. Please start a questionnaire with the intention of completing it before moving on to something else.

Thank you.

## The Hospital Anxiety Depression Scale (HADS)

This next questionnaire is designed to assess your general well being. Please read each item and TICK the reply that comes closest to **how you feel generally**. Note: Don't take too long over your replies; your immediate reaction to each item will probably be more accurate than a long thought out response.

| *Thinking about how I feel generally…* | |
|---|---|
| **I feel tense and 'wound up.'** | Most of the time<br>A lot of the time<br>From time to time<br>Not at all |
| **I still enjoy the things I used to enjoy.** | Definitely as much<br>Not quite so much<br>Only a little<br>Hardly at all |
| **I get a sort of frightened feeling as if something awful is about to happen.** | Very definitely and quite badly<br>Yes, but not too badly<br>A little, but it doesn't worry me<br>Not at all |
| **I can laugh and see the funny side of things.** | As much as I always could<br>Not quite so much now<br>Definitely not so much now<br>Not at all |
| **Worrying thoughts go through my mind.** | A great deal of the time<br>A lot of the time<br>From time to time but not too often<br>Only occasionally |
| **I feel cheerful.** | Not at all<br>Not often<br>Sometimes<br>Most of the time |
| **I can sit at ease and feel relaxed.** | Definitely<br>Usually<br>Not often<br>Not at all |

| *Thinking about how I feel generally...* | |
|---|---|
| **I feel as if I am slowed down.** | Nearly all the time<br>Very often<br>Sometimes<br>Not at all |
| **I get a sort of feeling like 'butterflies' in my stomach.** | Not at all<br>Occasionally<br>Quite often<br>Very often |
| **I have lost interest in my appearance.** | Definitely<br>I don't take as much care as I should<br>I may not take quite so much care<br>I take just as much care as ever |
| **I feel restless as if I have to be on the move.** | Very much indeed<br>Quite a lot<br>Not very much<br>Not at all |
| **I look forward with enjoyment to things.** | As much as I ever did<br>Rather less than I used to<br>Definitely less than I used to<br>Hardly at all |
| **I get sudden feelings of panic.** | Very often indeed<br>Quite often<br>Not very often<br>Not at all |
| **I can enjoy a good book, or radio, or TV programme.** | Often<br>Sometimes<br>Not often<br>Very seldom |

Please turn over.

## The General Tiredness Questionnaire (GTQ)

The following list of statements has been compiled from comments people have made about their general feelings of tiredness and energy in different circumstances. Please read each one carefully and indicate how much it applies to your normal, everyday state - that is, **how you are generally**. Circle one of the numbers on each line: **1** - disagree strongly; **2** - disagree; **3** - neither agree nor disagree; **4** - agree; **5** - agree strongly.

Note: Although some of the statements are similar to others, please respond to each one separately. Go through the list from beginning to end without leaving gaps or going back to change responses. Of course, there are no right or wrong answers - I am interested only in measuring the variety of experiences that people have in relation to feelings of tiredness and energy across a wide range of situations. A small number of items may not apply to everyone. If an item does not apply to you at all, please write N/A next to it.

| *Thinking of how I am generally...* | *Please circle <-disagree* | | | | *agree->* |
|---|---|---|---|---|---|
| I get tired for no reason. | 1 | 2 | 3 | 4 | 5 |
| I wake up feeling tired. | 1 | 2 | 3 | 4 | 5 |
| My capacity for concentration falls off later in the day. | 1 | 2 | 3 | 4 | 5 |
| I feel tired when I do a lot of physically demanding tasks. | 1 | 2 | 3 | 4 | 5 |
| I feel tired at the end of a full working day. | 1 | 2 | 3 | 4 | 5 |
| I feel alert most of the time. | 1 | 2 | 3 | 4 | 5 |

Please turn over.

| *Thinking of how I am generally…* | *Please circle* <br> *<-disagree* | | | | *agree->* |
|---|---|---|---|---|---|
| I get tired when I need to concentrate for long periods. | 1 | 2 | 3 | 4 | 5 |
| I take a long time to get going in the mornings. | 1 | 2 | 3 | 4 | 5 |
| I feel worn out after exerting myself physically. | 1 | 2 | 3 | 4 | 5 |
| Prolonged mental activity wears me out. | 1 | 2 | 3 | 4 | 5 |
| I feel tired in the evenings after working all day. | 1 | 2 | 3 | 4 | 5 |
| I am not a lively person. | 1 | 2 | 3 | 4 | 5 |
| Strenuous physical work exhausts me. | 1 | 2 | 3 | 4 | 5 |
| However tired I am I feel refreshed after sleep. | 1 | 2 | 3 | 4 | 5 |
| I don't feel like making much of an effort when I am tired. | 1 | 2 | 3 | 4 | 5 |
| When I am tired I tend to cut a few corners to get things done. | 1 | 2 | 3 | 4 | 5 |
| I think of myself as having bags of energy. | 1 | 2 | 3 | 4 | 5 |
| If I am doing something when tired I tend to skip less important details. | 1 | 2 | 3 | 4 | 5 |
| Physical work leaves me feeling worn out. | 1 | 2 | 3 | 4 | 5 |
| When I have to get up early I feel tired all day. | 1 | 2 | 3 | 4 | 5 |
| I feel most alert later in the day. | 1 | 2 | 3 | 4 | 5 |
| I am unable to sustain a high level of mental effort for long periods. | 1 | 2 | 3 | 4 | 5 |
| I am able to concentrate for long periods without lapses of attention. | 1 | 2 | 3 | 4 | 5 |
| If I am feeling tired during work I try to do less demanding tasks. | 1 | 2 | 3 | 4 | 5 |

Please turn over.

## Mental Toughness Questionnaire (MTQ)

Please indicate your response to the following items by circling one of the numbers, which have the following meaning:

**1** - Strongly disagree; **2** - Disagree; **3** - Neither agree or disagree; **4** - Agree; **5** - Strongly agree.

| | *Please circle <-never always->* | | | | |
|---|---|---|---|---|---|
| I usually find something to motivate me. | 1 | 2 | 3 | 4 | 5 |
| I generally feel in control. | 1 | 2 | 3 | 4 | 5 |
| I generally feel that I am a worthwhile person. | 1 | 2 | 3 | 4 | 5 |
| Challenges usually bring out the best in me. | 1 | 2 | 3 | 4 | 5 |
| When working with other people, I am usually quite influential. | 1 | 2 | 3 | 4 | 5 |
| Unexpected changes to my schedule generally throw me. | 1 | 2 | 3 | 4 | 5 |
| I don't usually give up under pressure. | 1 | 2 | 3 | 4 | 5 |
| I am generally confident in my own abilities. | 1 | 2 | 3 | 4 | 5 |
| I usually find myself just going through the motions. | 1 | 2 | 3 | 4 | 5 |
| At times, I expect things to go wrong. | 1 | 2 | 3 | 4 | 5 |
| "I just don't know where to begin" is a feeling I usually have when presented with several things to do at once. | 1 | 2 | 3 | 4 | 5 |
| I generally feel that I am in control of what happens in my life. | 1 | 2 | 3 | 4 | 5 |
| However bad things are, I usually feel they will work out positively in the end. | 1 | 2 | 3 | 4 | 5 |
| I often wish my life was more predictable. | 1 | 2 | 3 | 4 | 5 |

Please turn over.

**1** - Strongly disagree; **2** - Disagree; **3** - Neither agree or disagree;
**4** - Agree; **5** - Strongly agree.

| | Please circle <-never | | | | always-> |
|---|---|---|---|---|---|
| Whenever I try to plan something, unforeseen factors usually seem to wreck it. | 1 | 2 | 3 | 4 | 5 |
| I generally look on the bright side of life. | 1 | 2 | 3 | 4 | 5 |
| I usually speak my mind when I have something to say. | 1 | 2 | 3 | 4 | 5 |
| At times, I feel completely useless. | 1 | 2 | 3 | 4 | 5 |
| I can generally be relied upon to complete the tasks I am given. | 1 | 2 | 3 | 4 | 5 |
| I can usually take charge of a situation when I feel it is appropriate. | 1 | 2 | 3 | 4 | 5 |
| I generally find it hard to relax. | 1 | 2 | 3 | 4 | 5 |
| I am easily distracted from tasks that I am involved with. | 1 | 2 | 3 | 4 | 5 |
| I generally cope well with any problems that occur. | 1 | 2 | 3 | 4 | 5 |
| I do not usually criticise myself, even when things go wrong. | 1 | 2 | 3 | 4 | 5 |
| I generally try to give 100% | 1 | 2 | 3 | 4 | 5 |
| When I am upset or annoyed, I usually let others know. | 1 | 2 | 3 | 4 | 5 |
| I tend to worry about things well before they actually happen. | 1 | 2 | 3 | 4 | 5 |
| I often feel intimidated in social gatherings. | 1 | 2 | 3 | 4 | 5 |
| When faced with difficulties, I usually give up. | 1 | 2 | 3 | 4 | 5 |

Please turn over.

**1** - Strongly disagree; **2** - Disagree; **3** - Neither agree or disagree;
**4** - Agree; **5** - Strongly agree.

| | *Please circle* <br> *<-never always->* | | | | |
|---|---|---|---|---|---|
| I am generally able to react quickly when something unexpected happens. | 1 | 2 | 3 | 4 | 5 |
| Even when under considerable pressure, I usually remain calm. | 1 | 2 | 3 | 4 | 5 |
| If something can go wrong, it usually will. | 1 | 2 | 3 | 4 | 5 |
| Things just usually happen to me. | 1 | 2 | 3 | 4 | 5 |
| I generally hide my emotions from others. | 1 | 2 | 3 | 4 | 5 |
| I usually find it difficult to make a mental effort when I am tired. | 1 | 2 | 3 | 4 | 5 |
| When I make mistakes, I usually let it worry me for days afterwards. | 1 | 2 | 3 | 4 | 5 |
| When I am feeling tired, I find it difficult to get going. | 1 | 2 | 3 | 4 | 5 |
| I am comfortable telling people what to do. | 1 | 2 | 3 | 4 | 5 |
| I can normally sustain high levels of mental effort for long periods. | 1 | 2 | 3 | 4 | 5 |
| I usually look for changes in my routine. | 1 | 2 | 3 | 4 | 5 |
| I feel that what I do tends to make no difference. | 1 | 2 | 3 | 4 | 5 |
| I usually find it hard to summon enthusiasm for the tasks that I face. | 1 | 2 | 3 | 4 | 5 |
| If I feel somebody is wrong, I am not afraid to argue with them. | 1 | 2 | 3 | 4 | 5 |
| I usually enjoy a challenge. | 1 | 2 | 3 | 4 | 5 |
| I can usually control my nervousness. | 1 | 2 | 3 | 4 | 5 |
| In discussions, I tend to back-down even when I feel strongly about something. | 1 | 2 | 3 | 4 | 5 |
| When I face setbacks, I am often unable to persist with my goal. | 1 | 2 | 3 | 4 | 5 |
| I can usually adapt myself to challenges that come my way. | 1 | 2 | 3 | 4 | 5 |

## The Tinnitus Cognitions Questionnaire (TCQ)

For each item below, please indicate how often you have been aware of thinking a particular thought on occasions when you have noticed the tinnitus.

Circle one of the numbers on each line: **1** -never; **2** - rarely; **3** - occasionally; **4** - frequently; **5** - very frequently.

| | *Please circle* <br> *<-never* | | | | *always->* |
|---|---|---|---|---|---|
| I think "If only the noise would go away" | 1 | 2 | 3 | 4 | 5 |
| I think "Why me? Why do I have to suffer this horrible noise?" | 1 | 2 | 3 | 4 | 5 |
| I think "What did I do to deserve this?" | 1 | 2 | 3 | 4 | 5 |
| I think "The noise makes my life unbearable." | 1 | 2 | 3 | 4 | 5 |
| I think "Nobody understands how bad the noise is." | 1 | 2 | 3 | 4 | 5 |
| I think "If only I could get some piece and quiet." | 1 | 2 | 3 | 4 | 5 |
| I think "I can't enjoy what I'm doing because of the noise." | 1 | 2 | 3 | 4 | 5 |
| I think "How can I go on putting up with this noise?" | 1 | 2 | 3 | 4 | 5 |
| I think "The noise will drive me crazy." | 1 | 2 | 3 | 4 | 5 |
| I think "Why can't anyone help me?" | 1 | 2 | 3 | 4 | 5 |
| I think "My tinnitus is never going to get better." | 1 | 2 | 3 | 4 | 5 |
| I think "The noise will overwhelm me." | 1 | 2 | 3 | 4 | 5 |
| I think "With this noise, life is not worth living." | 1 | 2 | 3 | 4 | 5 |

Please turn over.

Circle one of the numbers on each line: **1** –never; **2** – rarely; **3** – occasionally; **4** – frequently; **5** – very frequently.

| | Please circle<br><-never always-> | | | | |
|---|---|---|---|---|---|
| I think "No matter how unpleasant the noise gets, I can cope." | 1 | 2 | 3 | 4 | 5 |
| I think "The noise might be unpleasant but it won't drive me crazy." | 1 | 2 | 3 | 4 | 5 |
| I think "I'll be able to enjoy things if I keep my attention off the noise." | 1 | 2 | 3 | 4 | 5 |
| I think "I'm not the only person with tinnitus." | 1 | 2 | 3 | 4 | 5 |
| I think "There are worse things in life than tinnitus." | 1 | 2 | 3 | 4 | 5 |
| I think "The noise will eventually get less annoying if I try to distract myself from it." | 1 | 2 | 3 | 4 | 5 |
| I think "I have coped with the noise before, so I can cope again this time." | 1 | 2 | 3 | 4 | 5 |
| I say to myself "It will help if I try to think of something pleasant." | 1 | 2 | 3 | 4 | 5 |
| I tell myself "I can learn to live with it." | 1 | 2 | 3 | 4 | 5 |
| I think "The noise might be there but I can still enjoy things." | 1 | 2 | 3 | 4 | 5 |
| I tell myself "Think of something else other than the noise." | 1 | 2 | 3 | 4 | 5 |
| I tell myself "I won't think about the noise." | 1 | 2 | 3 | 4 | 5 |
| I think "The noise is a nuisance but I just won't let it bother me." | 1 | 2 | 3 | 4 | 5 |

Thank you.

Which is the *Odd One Out*? One letter is different from the other three.
Ignoring size and colour, cross out the *Odd One Out* in each set as quickly as you can.

| | | | |
|---|---|---|---|
| AATa | DdDG | Ttht | ABbB |
| GgGD | abaA | HTtT | dgdD |
| thTt | bBba | hHBH | Gdgg |
| Thtt | BbBA | baAa | GGDg |
| thHh | AaAB | gdgG | abBb |
| Ddgd | tTHT | HTHh | DdDG |

Which is the Odd One Out? One letter is different from the other three.
Ignoring size and colour, cross out the Odd One Out in each set as quickly as you can.

| | | | |
|---|---|---|---|
| Thtt | BbBA | baAa | GGDg |
| thHh | AaAB | gdgG | abBb |
| Ddgd | tTHT | HTHh | DdDG |
| GgGD | AATa | ABbB | HTtT |
| DdDG | thTt | Ttht | Gdgg |
| hHBH | abaA | bBba | dgdD |

Which is the *Odd One Out*? One letter is different from the other three.
Ignoring size and colour, cross out the *Odd One Out* in each set as quickly as you can.

| | | | |
|---|---|---|---|
| bBba | GGDg | baAa | hHBH |
| HTtT | Thtt | gdgG | abBb |
| dgdD | AATa | ABbB | Gdgg |
| DdDG | thTt | Ttht | BbBA |
| abaA | GgGD | Ddgd | thHh |
| tTHT | AaAB | HTHh | DdDG |

Which is the Odd One Out? One letter is different from the other three.
Ignoring size and colour, cross out the Odd One Out in each set as quickly as you can.

| | | | |
|---|---|---|---|
| GGDg | Thtt | baAa | dgdD |
| HTtT | ABbB | gdgG | hHBH |
| thTt | AATa | DdDG | GgGD |
| BbBA | Gdgg | Ttht | abaA |
| bBba | thHh | abBb | Ddgd |
| tTHT | AaAB | HTHh | DdDG |

Supplementary Table (Study One)

*Correlation Matrix between HADS sub-scales and measures of relevant task performance (i.e. tasks with significant differences between groups)*

| Performance Measures (Study One) | HADS (Anxiety) | HADS (Depression) |
|---|---|---|
| Rule of Letter (O3) (mean reaction time) | -.022 | .087 |
| Rule of Letter (O3) (errors made) | .065 | -.039 |
| SAT (mean reaction time) | -.279 | -.158 |
| SAT (errors made) | -.046 | .125 |
| Stroop (mean reaction time) | -.111 | .012 |
| Stroop (errors made) | -.041 | .090 |
| VDT - Stage Three (correct responses) | -.077 | -.019 |

# Consent Form

Thank you for agreeing to participate in this study - it will go a long way towards the completion of my PhD. Thesis. This experiment will require you to complete four different tasks as well as fill in a small number of questionnaires (two to three, depending). At the end of each task, you will also be asked for your personal opinion on how challenging you found each task to be.

Note to tinnitus sufferers: There will also be times during this experiment when you will be asked how aware of your tinnitus you are. Such questions, by their very nature, will draw your attention to the sounds. If you still wish to participate, please complete the questions below.

Name: Age: Gender:

Future contact details:
(Address and/or e-mail)

Signature:

After each and every experiment, you will be asked how difficult you personally found the tasks to be. This will be a subjective viewpoint and will be measured by a five-point scale.

| Very easy | Quite easy | Neither easy or hard | Quite difficult | Very challenging |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

In every case, please consider what each task demanded from you in order to complete it, and assign the value to the difficulty scale that you think is the most appropriate.

---

If you are a tinnitus sufferer, you will also be asked to provide a subjective rating of how bearable your tinnitus is at particular moments in time during the course of your participation in this study. This is also a highly subjective measurement and will be measured on a similar scale.

| Very quiet | Quieter than average | No louder or quieter than normal | Louder than average | Very loud |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

Without dwelling on it too much, please indicate your current awareness of your tinnitus as compared to its normal level.

# Subjective Difficulty Ratings

| Experiment One | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

| Experiment Two | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

| Experiment Three | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

| Experiment Four | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

## Subjective Tinnitus Ratings

| Before Experiment One (start) | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

| After Experiment One | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

| After Experiment Two | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

| After Experiment Three | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

| After Experiment Four (end) | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

# Clock Task

This task is essentially a monitoring task. It is a test of your continuing vigilance over time. When the task begins, you will be aware of a series of circles on the computer screen, mimicking a 12hr clock face.

As the seconds tick by, the coloured quadrant will slowly move clockwise around the screen, from one circle to the next. Your task is to watch this coloured quadrant closely. Every now and again, at long and irregular intervals, the coloured quadrant will skip a sector, moving *double* the usual distance. Press the left mouse button as soon as you notice one of these double-length movements.

Please note that this is a task demanding constant attention. Please try your best to keep concentrating throughout.

There are two sections to the test. The first is a short practice run to ensure familiarity with what you have to accomplish. The experimenter will watch the clock tick away alongside you and help to identify each signal.

The second part is much longer, lasting twenty minutes. This will be the most challenging section by far. Be vigilant!

# The Grid Task

This task involves you watching a grid of letters. You will face only these four letters.

b d p q

These four letters have been chosen as they are very similar in shape. The task involves a grid full of these letters. As the task proceeds, the background of different boxes will highlight in red. Your task is to press the space bar whenever any box containing the letter '**b**' is highlighted. If any of the other letters are highlighted, *do nothing.*

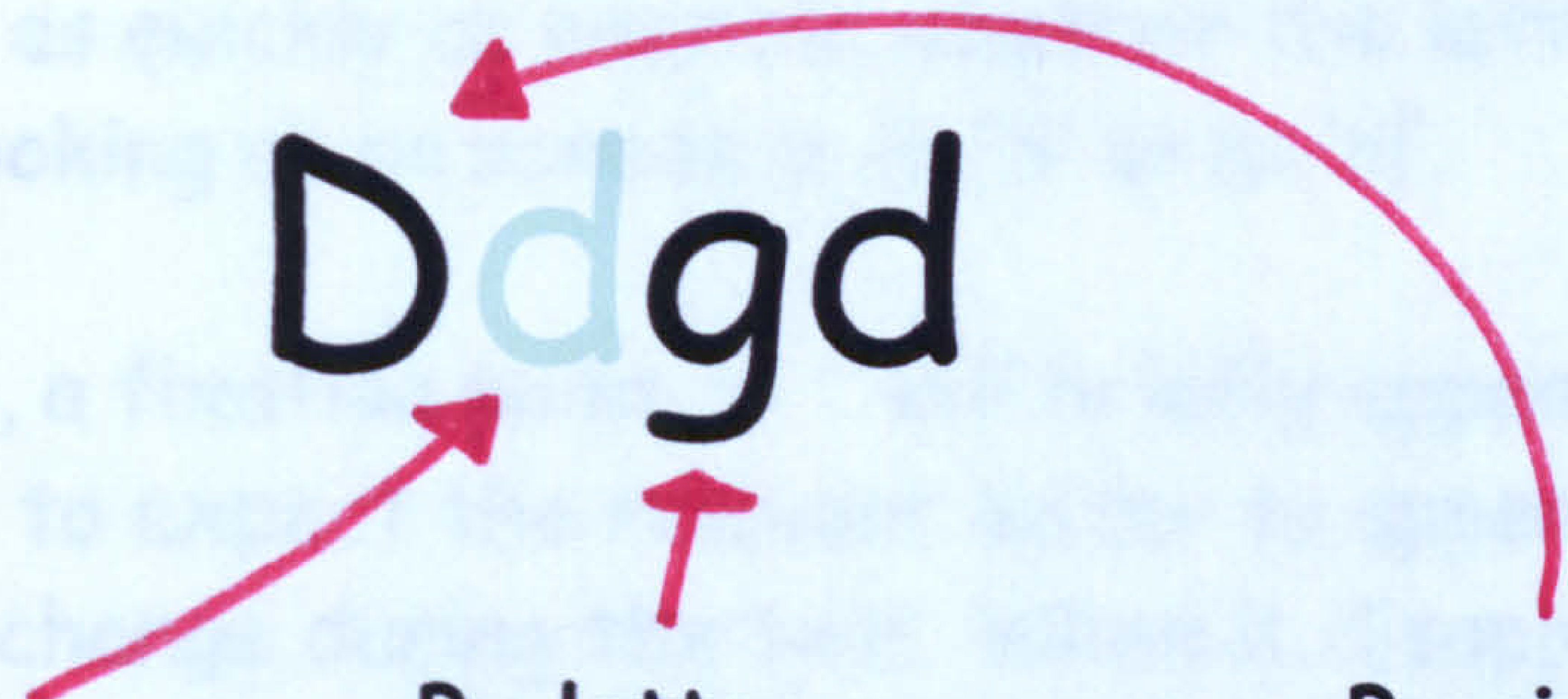
There will be two grids shown to you. The first grid will be small and the test itself will be short. This will not count and will only help to familiarise you with the task at hand.

The second grid you face will be more demanding, being larger, moving faster and taking longer to complete. Again, watch out for and respond to the letter '**b**' only.

If you have any questions, now is the time to ask them.

# The Odd One Out ($O^3$) Task

The following task involves you studying blocks of letters, each block having an odd one out. This odd one out can chosen by any of three different methods. For example:




| **By colour** | **By letter** | **By size** |
|---|---|---|
| (1 green; 3 black) | (1 g; 3 d's) | (1 capital; 3 small) |

For the purpose of this experiment, you will be asked only to use the rule of *letter* and to ignore the other methods. They are merely there to distract you. Here is another example:

thHh

We are only going to be using the rule of *letter*. Above there are three H's and one t. Therefore, the odd one out is the t.

When we start, you will be given a page containing 24 blocks of letters. You will be timed - by stopwatch - as you draw a line through each 'odd one out'. There will be four pages in total and you will be times for each one separately.

If you are unhappy with the instructions for your task, please ask any questions now. If not, we'll begin. Remember, speed and accuracy are both equally important.

# Selective Attention Task

The following task is based upon letter recognition. It is generally agreed that 'S' and 'H' are the two letters in the alphabet that are least like each other. For this test, you will have to decide as quickly as possible whether the letter you are looking at on screen is an 'S' or an 'H'.

When you begin, a fixation point " + " will briefly appear. This tells you where to expect the relevant letter to appear. This point will never change during the test. When it disappears, it will be replaced by either an 'S' or an 'H'. You must then press the corresponding button on the keyboard. The first few trials are part of a demonstration run and after these five trials, you will be told whether you were correct or incorrect.

Once the practice run is complete, you will have an opportunity to ask any questions before the actual experiment begins.

Please note that sometimes, the letter will have *flankers*, other letters to each side, there to distract you. For example:

| Example One | Example Two |
|---|---|
| P S P | H S H |

These letters are flankers. Ignore them. In both examples, you would press the letter 'S' as it is the letter in the middle.

Table 39

*Correlations between Subjective Tinnitus Severity Scale (STSS) scores and the various performance measure of the Study Two tasks (n = 36)*

| | STSS | Grid Task (RT) | Grid Task (errors) | MCT (RT) | MCT (errors) | O3 (RT) | O3 (errors) | SAT (RT) |
|---|---|---|---|---|---|---|---|---|
| **Grid Task (RT)** | .262 | | | | | | | |
| **Grid Task (errors)** | .447** | .233 | | | | | | |
| **MCT (RT)** | .030 | -.032 | .195 | | | | | |
| **MCT (errors)** | .493** | .233 | .500** | .215 | | | | |
| **O3 (RT)** | -.015 | -.438* | -.156 | -.059 | -.171 | | | |
| **O3 (errors)** | -.164 | .099 | .267 | -.002 | -.170 | .107 | | |
| **SAT (RT)** | -.050 | -.080 | -.180 | .078 | -.213 | -.050 | .045 | |
| **SAT (errors)** | .115 | .139 | .404* | .036 | .190 | .115 | .393* | -.123 |

James G. Jackson
Department of Psychology,
University of Hull,
Hull,
HU6 7RX.
(01482) 465587.
J.G.Jackson@hull.ac.uk

Dear

Please find enclosed everything that you will need to complete the first week of the diary study. You should have:

- A plastic wallet containing the instructions for completing the diary.
- A confidential questionnaire to collect general data. This will not be shown to anybody else at any stage. It will merely allow for trends and ease of contact etc...
- The Subjective Tinnitus Severity Scale (STSS). This questionnaire will measure *your* perception of your tinnitus.
- The Hospital Anxiety and Depression Scale (HADS). This questionnaire measures levels of anxiety and depression.
- The Mental Toughness Questionnaire (MTQ48). This questionnaire measures your ability to cope with situations.
- The diary itself. Seven days worth. Each 'day' of the diary contains three sheets stapled together. Yellow for morning, green for afternoon and blue for early evening.
- Freepost SAE in order to return the above.

What you are now required to do is complete the three questionnaires, namely the STSS, the GWS and the MTQ48. These are what we refer to as *trait* questionnaires. They do not change quickly over time. As such, it doesn't really matter when you complete them. You will only be asked to complete them once.

Then there is the diary itself. Rather than give you a booklet, I have decided to make each day separate in order for them to be easier to carry about. Following the instructions provided, please fill them in every day. Once you have completed all seven, post them (and the other three questionnaires) back to me at the University.

In seven days time, I will post out the next week of diary and so on, until the six weeks are up. If you plan to go on holiday, take a break etc... then do let me know. I can send more 'days' in one go. After all, it would be very valuable to continue the diary through such a time - your tinnitus will most likely change greatly under such circumstances. However, do not feel obliged to do so. As stated in the instructions, do not feel the need to fill in this diary at each and every stage of each and every day. Not if it is inconvenient or difficult to do so. I don't want this to be a chore for people. Just try to fill it in as often as you can. However, I cannot stress enough how important your time is to me, and how much I appreciate your interest in this study. I am sure that you will find it valuable and that the feedback you will receive afterwards will be of use in helping you to understand your tinnitus that bit better.

If you have any questions, then don't hesitate to contact me. Thank you once more for your time.

Yours Sincerely,

James G. Jackson.

This is a confidential questionnaire that is designed to do two things. Firstly, it is to collect some brief background biodata. Secondly, to provide a number of ways to contact you should the need arise.

Name:

Age: Gender (Male/Female):

Contact Address:
(If not known to me)

Contact telephone number:

Contact e-mail address:
(If you have one).

How long have you had tinnitus (in years)?:

## General information:

Please read this information before you start the diary, and refer back whenever you are not sure what is meant by an item - particularly early on. The diary is designed to cover a wide range of experiences but only take a few minutes each day to complete. Please take care when making your responses. Try to use the whole range over the course of the diary to reflect the diversity of your experiences, and to be as accurate as you can. With subjective experiences there are, of course, no absolute highs and lows. The labels only refer to your own range of experience. So when asked about how energetic/tired you feel, circle a high number (say '7' or '8') if you feel tired (for you); if you feel fairly energetic, circle a lower number instead (say '3' or '4'). As an example of the 1-9 scales, a '1' here means as energetic as you have ever felt and a '9' would mean as tired as you have ever felt. '5' is your average perceived level of the balance between energy and tiredness, with '4' and '6' indicating feelings just on either side of this average level.

## Day and times:

This diary needs to be filled in at three different points during the day: in the morning at breakfast (say 8-9am); at lunchtime (12noon-1pm or thereabouts); and in the early evening, roughly 6-7pm or just after dinner. Please try to complete it. If you do happen to miss a day or even a part of a day, *don't worry.* Just miss that one out carry on as normal when you can.

## Part One: In the morning

This section is concerned with the hour or so after you've got up in the morning. It first asks you about the quality of your sleep the night before, and the total of hours slept. Please respond in such a way so that a '5' represents *your* average night's rest, a '9' represents a very restful night's sleep and a '1' indicates a very poor quality of sleep.

It then asks you to consider how bad (or not) your tinnitus was as you were trying to get to sleep this night before, followed by how you severe (or not) you judge your tinnitus to be now. These questions are subjective and depend on your own personal experience. Please try to answer them by comparison with how your tinnitus usually sounds.

After these are questions referring to your general mood, being indicators of various states of well-being. You are asked to indicate how you feel in terms of several dimensions used to indicate different aspects of mood. Please circle the number that best describes how you feel, between the two extremes for each dimension. For example, the first question measures enthusiasm/misery. A '5' here would indicate neither one nor the other.

The next table measures demands opportunities and support. Both work and 'non-work' can be thought of as making demands on you, as well as providing opportunities for you to meet these demands, both with and without support.
***Emotional demands:*** tasks or encounters which put a load on your emotional capacity; activities which challenge your emotional stability; having to be concerned with the well-being of others; having to deal with unpleasant events; personal conflicts; threats and disappointments.
***Mental demands:*** essentially mental work; thinking, problem solving, decision making, planning etc.; tasks which stretch your mental capacity; work requiring a lot of concentration and mental effort; having many different things to do; having to call on detailed knowledge and skill.

***Physical demands:*** essentially physical work; tasks which place a load on your musculo-skeletal system; work requiring overt physical activity (but not necessarily mentally demanding); being on your feet a lot; lifting and carrying heavy objects; moving around a great deal in the day.
***Personal control:*** the opportunity to use discretion and freedom of choice in how you spend your time; having a flexible structure for getting things done; being able to plan your own activities - to decide how, when, and in which order jobs should be carried out; flexibility of taking breaks, etc.
***Personal support:*** the availability of help and support of all kinds from other people and environmental factors; having someone to confide in or depend on; help with difficult tasks; having access to reliable facilities/equipment; availability of clear guidelines and advice.
***Getting things done:*** how successful were you in completing any planned activities, or responding to the cognitive demands made on you to carry out jobs and tasks?
***Getting on well with others:*** how successful were you in using your social and interpersonal skills - in meeting the emotional needs you perceived in others?
***Taking care of your own needs:*** How successful were you in managing your own emotional needs - of taking your own wishes into account?

Finally, you are asked as to the amount of concentration, effort and time demanded of you in the last fifteen minutes prior to competing this first section and also the time pressure that you were under. Again, these answers are subjective, and must be judged with regards to what you normally face at this time of day. There is also a small space to briefly describe just what you have been up to.

**Part Two: Midday/lunchtime**

This section is not so concerned with a specific time, merely the time of day that you take a break for lunch. However, it would be beneficial if you complete this section at roughly the same time every day, so as to maintain the consistency of your answers. All the questions are ones that you have seen in Part One.

**Part Three: Early Evening**

Part Three is to be completed in the early evening, perhaps when you have come home from work or after you have eaten your evening meal. Again, please try to pick a time of day that suits your schedule and then stick to it for consistency. Don't worry if this is not always possible. Apart from the regular items, Part Three also contains one further question asking after your overall sense of how your tinnitus has been throughout the whole of the day, rather than any specific time. As always, this question is subjective and gives you a chance to state how your tinnitus has been at times other than the set points already mentioned. There is also space to bring up any comments of your own regarding the day in question. Please feel free to add anything that you think may be relevant.

On first glance, this may seem to be a lot of work on your part. However, with practice, this questionnaire will take up only a few minutes of your day and will be invaluable in helping to ascertain what may or may not have an effect on your perception of your tinnitus. Many thanks for your co-operation - do call or contact me at any time if you have any queries.

James Jackson (Hull University): 01482 (46)5587.
J.G.Jackson@hull.ac.uk

Date: / /2004; PART ONE: to be completed in the morning.

| | | | |
|---|---|---|---|
| How well did you sleep last night? | Poorly | 1 2 3 4 5 6 7 8 9 | Very well |

Total number of hours slept? ______ hours.

How would you describe your tinnitus LAST NIGHT as you were trying to sleep?

| | | | | |
|---|---|---|---|---|
| Very quiet | Quieter than average | No louder or quieter than normal | Louder than average | Very loud |

How would you describe your tinnitus AT THIS VERY MOMENT?

| | | | | |
|---|---|---|---|---|
| Very quiet | Quieter than average | No louder or quieter than normal | Louder than average | Very loud |

Please indicate how you feel RIGHT NOW, circling the appropriate number.

| | | |
|---|---|---|
| Enthusiastic | 1 2 3 4 5 6 7 8 9 | Miserable |
| Weary | 1 2 3 4 5 6 7 8 9 | Lively |
| Relaxed | 1 2 3 4 5 6 7 8 9 | Tense |
| Depressed | 1 2 3 4 5 6 7 8 9 | Optimistic |
| Energetic | 1 2 3 4 5 6 7 8 9 | Tired |
| On edge | 1 2 3 4 5 6 7 8 9 | At ease |

Please indicate the demands, level of control and support that you have, and the level of effectiveness you are experiencing at THIS MOMENT in the day. (1 = lowest; 9 = highest).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Emotional demands | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Mental demands | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Physical demands | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Levels of personal control experienced | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Levels of personal support experienced | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Effectiveness in getting things done | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Effectiveness in getting on well with others | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Effectiveness in taking care of your own needs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

How much concentration has been required in the last FIFTEEN MINUTES?

| | | | | |
|---|---|---|---|---|
| None whatsoever | Not very much | No more than normal | An awful lot | Intense concentration |

How much effort has been demanded of you in the last FIFTEEN MINUTES?

| | | | | |
|---|---|---|---|---|
| No effort at all | Not very much effort | No more than normal | Quite a lot of effort | A great deal of effort |

How much time pressure have you been under in the last FIFTEEN MINUTES?

| | | | | |
|---|---|---|---|---|
| None whatsoever | Not very much | No more than normal | An awful lot | Intense pressure |

Briefly, what have you been up to in the last FIFTEEN MINUTES?

Date: / /2004; PART TWO: to be completed at lunchtime.

How would you describe your tinnitus AT THIS VERY MOMENT?

| | | | | |
|---|---|---|---|---|
| Very quiet | Quieter than average | No louder or quieter than normal | Louder than average | Very loud |

Please indicate how you feel RIGHT NOW, circling the appropriate number.

| | | |
|---|---|---|
| Enthusiastic | 1 2 3 4 5 6 7 8 9 | Miserable |
| Weary | 1 2 3 4 5 6 7 8 9 | Lively |
| Relaxed | 1 2 3 4 5 6 7 8 9 | Tense |
| Depressed | 1 2 3 4 5 6 7 8 9 | Optimistic |
| Energetic | 1 2 3 4 5 6 7 8 9 | Tired |
| On edge | 1 2 3 4 5 6 7 8 9 | At ease |

Please indicate the demands, level of control and support that you have, and the level of effectiveness you are experiencing at THIS MOMENT in the day. (1 = lowest; 9 = highest).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Emotional demands | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Mental demands | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Physical demands | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Levels of personal control experienced | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Levels of personal support experienced | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Effectiveness in getting things done | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Effectiveness in getting on well with others | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Effectiveness in taking care of your own needs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

How much concentration has been required in the last FIFTEEN MINUTES?

| | | | | |
|---|---|---|---|---|
| None whatsoever | Not very much | No more than normal | An awful lot | Intense concentration |

How much effort has been demanded of you in the last FIFTEEN MINUTES?

| | | | | |
|---|---|---|---|---|
| No effort at all | Not very much effort | No more than normal | Quite a lot of effort | A great deal of effort |

How much time pressure have you been under in the last FIFTEEN MINUTES?

| | | | | |
|---|---|---|---|---|
| None whatsoever | Not very much | No more than normal | An awful lot | Intense pressure |

Briefly, what have you been up to in the last FIFTEEN MINUTES?

Date: / /2004; PART ONE: to be completed in the evening.

How would you describe your tinnitus AT THIS VERY MOMENT?

| | | | | |
|---|---|---|---|---|
| Very quiet | Quieter than average | No louder or quieter than normal | Louder than average | Very loud |

Please indicate how you feel RIGHT NOW, circling the appropriate number.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Enthusiastic | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Miserable |
| Weary | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Lively |
| Relaxed | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Tense |
| Depressed | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Optimistic |
| Energetic | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Tired |
| On edge | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | At ease |

Please indicate the demands, level of control and support that you have, and the level of effectiveness you are experiencing at THIS MOMENT in the day. (1 = lowest; 9 = highest).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Emotional demands | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Mental demands | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Physical demands | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Levels of personal control experienced | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Levels of personal support experienced | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Effectiveness in getting things done | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Effectiveness in getting on well with others | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Effectiveness in taking care of your own needs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

How much concentration has been required in the last FIFTEEN MINUTES?

| | | | | |
|---|---|---|---|---|
| None whatsoever | Not very much | No more than normal | An awful lot | Intense concentration |

How much effort has been demanded of you in the last FIFTEEN MINUTES?

| | | | | |
|---|---|---|---|---|
| No effort at all | Not very much effort | No more than normal | Quite a lot of effort | A great deal of effort |

How much time pressure have you been under in the last FIFTEEN MINUTES?

| | | | | |
|---|---|---|---|---|
| None whatsoever | Not very much | No more than normal | An awful lot | Intense pressure |

Briefly, what have you been up to in the last FIFTEEN MINUTES?

Finally, how would you describe your tinnitus OVERALL, during the course of today?

| | | | | |
|---|---|---|---|---|
| Very quiet | Quieter than average | No louder or quieter than normal | Louder than average | Very loud |

Any further comments: