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A preliminary investigation of potential cognitive performance decrements in non-help-seeking tinnitus sufferers

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Key Words: Anxiety, Cognitive Performance, Tinnitus

Abbreviations:

ANOVA – Analysis of Variance

DV – Dependent Variable

HADS – Hospital Anxiety Depression Scale

IV – Independent Variable

LSD – Least Significant Differences

MANOVA – Multivariate Analysis of Variance

STSS – Subjective Tinnitus Severity Scale

VDT – Vienna Determination Task

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Abstract

Objective: The aim of the study was to investigate the possible impact of tinnitus on the performance of challenging cognitive tasks. *Design*: Participants completed the Hospital Anxiety and Depression Scale and completed two cognitive tasks: the Vienna Determination Task and a variant of the Stroop Paradigm. In addition, tinnitus sufferers completed the Subjective Tinnitus Severity Scale. *Study Sample*: 33 tinnitus sufferers and 33 controls took part in the study (n=66). *Results*: Tinnitus sufferers were no more depressed nor anxious than controls, but they performed less well on both cognitive tasks. *Conclusions*: Possible causes and implications of these performance decrements are discussed, with particular attention given to the possibility that subjective distress is an important moderating factor in tinnitus sufferers.

Tinnitus is the medical term for what has traditionally been described as a subjective ringing or buzzing sound that comes from inside the head in the absence of corresponding external stimuli (Thomas, 1993). Much work has been devoted to identifying symptoms inherent to tinnitus distress (e.g. Erlandsson, Hallberg & Axelsson, 1992; Attias et al., 1995), but surprisingly few studies have looked at the effects of tinnitus on cognition, even though many studies state that tinnitus sufferers report concentration difficulties (e.g. Tyler & Baker, 1983; Hallam, Jakes & Hinchcliffe, 1988; Rizzardo et al., 1998).

It was Jastreboff (1990) who first proposed a comprehensive neurophysiological model of tinnitus which was able to explain how a seemingly non-threatening stimulus could cause agitation and real distress in sufferers. Here, peripheral ear damage results in random and spontaneous signals being sent to the limbic system as well as the auditory cortex, and it is in the former that emotional associations are made which result in the tinnitus signal being perceived as threatening and unpleasant (Jastreboff & Hazell, 2004). The strength of this model is that the interaction between the limbic system and the autonomic nervous system is subconscious, involving mechanisms that we have no direct or deliberate control over. As such, it is individual appraisal that matters and not physical characteristics such as loudness or pitch (Jastreboff, Gray & Gold, 1996).

Initial work by Andersson et al. (2000) illustrated that tinnitus sufferers perform less well in cognitive tasks such as the Stroop Paradigm (Stroop, 1935; cited in Küper & Heil, 2012). Since the Stoop Paradigm is a task of attentional interference and is not auditory in nature, this is indicative that attending to the tinnitus sensation draws on general mental resources (i.e. the central executive) rather than auditory resources (Baddeley, 1986). Further evidence that tinnitus may impair non-auditory cognitive performance comes from the work of Hallam et al. (2004) who concluded that tinnitus sufferers perform less well when inhibiting task-irrelevant activity, and also from Rossiter et al. (2006) who evidenced that tinnitus affects working memory. They also confirmed that while tinnitus sufferers performed well in a baseline condition, overall performance fell significantly during a difficult task of divided attention. More evidence has been provided by Stevens et al. (2007) who showed once again that the presence of tinnitus affects performance on attentional tasks.

In addition, Burton et al. (2012) has recently reported that the presence of bothersome tinnitus is enough to bring about synaptic change, specifically reporting that tinnitus alters connectivity in the fronto-insular cortex, an area of the brain involved in maintaining attention (e.g. Sridharan, Levitin & Menon, 2008). At this point in time, greater clarity is required to appreciate whether cognitive decrement in tinnitus sufferers is due to tinnitus, indirect psychological effects caused by tinnitus (e.g. anxiety), or a combination of the two. This preliminary study is an attempt to specifically compare task performance between a control group and a tinnitus group reporting low to moderate tinnitus severity.

We hypothesise that tinnitus sufferers are disadvantaged during challenging cognitive tasks that require use of the Central Executive. In other words, with greater tinnitus distress comes greater allocation of finite resources to the tinnitus sensation (i.e. the threat), and a reduction in what remains available to be allocated to any task at hand. Our second aim is to consider the indirect effects of the tinnitus sensation. For example, there is a strong comorbidity between tinnitus and anxiety (e.g. Robinson et al., 2007), and that anti-depressant intervention aimed at reducing tinnitus severity can also lead to reductions in symptoms of depression and anxiety (e.g. Zoger et al., 2006). Therefore, this study is a comparison between a control group and a moderate tinnitus population across two distinct cognitive tasks. If the poor cognitive performance previously found in other studies is replicated, then this suggests the very presence of tinnitus is enough. If the moderate tinnitus sample is comparable in performance, then this would suggest that other factors are moderating cognitive performance in tinnitus sufferers.

Method

Participants

All participants (n=66) were recruited through word-of-mouth, by university advertisements, and by use of local media. Local audiology clinics were avoided, and any tinnitus sufferer who had previously sought help from their GP, their local hospital or a self-help group was discounted. Control participants were sought through the social circle of tinnitus sufferers in the first instance, and institution/local advertisements in the second. When attending, participants were asked to complete the Subjective Tinnitus Severity Scale (STSS; Halford & Andersson, 1991a) with scores above zero indicating the presence of tinnitus. All tinnitus participants were asked to confirm they had never sought any treatment or therapy for their tinnitus. Furthermore, all participants were asked to confirm they did not suffer from colour-blindness or other sight-related disorders, that they were comfortable conversing in quiet surroundings, that they did not wear or had previously been advised to wear hearing aids, and that English was their first language. If a tinnitus sufferer reported previous treatment requests or if any of the other filter questions were answered in the affirmative, the experiment would have ended there with participants debriefed accordingly. The 33 tinnitus volunteers (17 males and 16 females) were compared with 33 controls (16 males and 17 females). In order to neutralize possible confounding effects of age, attempts were also made to match both groups along this variable. The mean age of the control group was 45.12yrs (s.d. = 14.74) and the mean age of the tinnitus group was 48.18yrs (s.d. = 17.07). A two-way ANOVA [$F(1, 64) = 0.61$; $p = 0.438$ns.] indicated that this three year age difference was not significant.

Materials

Subjective Tinnitus Severity Scale (STSS): The STSS (Halford & Andersson, 1991a) is a 16-item dichotomous yes/no questionnaire providing a potential range of scores from 0-16 indicating how intrusive each participant believes their tinnitus sensation to be. Example items include "Does your tinnitus make it difficult for you to concentrate?" and "Does your tinnitus frequently upset you?". These forced-choice items are simple to respond to, and are advantageous in that they do not give participants the option of a partial positive answer. While the STSS is an older questionnaire, it is psychometrically sound and provides clinically-supported boundaries indicative of tinnitus severity; i.e. Halford and Andersson suggested a score of twelve or more was indicative of 'severe tinnitus', and reported an alpha coefficient of 0.90 for the scale itself, with scores also correlating strongly with two independent clinical ratings (0.76 and 0.73 respectively). Newman and Sandridge (2004) suggest a Cronbach's Alpha value of 0.84 for the scale. With a sample of 104 tinnitus sufferers, Van Veen et al. (1998) compared the STSS to a number of other subjective tinnitus scales and reported significant correlations, also noting that STSS scores were independent of age and the reported duration of the tinnitus sensation.

The Hospital Anxiety and Depression Scale (HADS): The HADS was originally designed for outpatient departments (Zigmond & Snaith, 1983) with care being taken to ensure that scores would not be affected by the presence of injury or disease. It is a 14-item questionnaire, with seven items measuring anxiety and seven more measuring depression. Example items include "I still enjoy the things I used to enjoy" and "I get sudden feelings of panic", with participants registering their agreement on a scale of 0-3, resulting in a score of 0-21 for each 7-item subscale. Scores of 8-11 may be considered 'borderline' (p. 365), whereas higher scores indicate possible dysfunction. Internal consistencies of both subscales are good, with scores of 0.80-0.93 for anxiety and 0.81-0.90 for depression (Hermann, 1997). Test-retest reliability shows a high correlation after three weeks ($r = 0.80$), gradually reducing over longer time intervals. The mean correlation from eighteen separate studies (n = 8,160) is r = 0.63, indicating that HADS is stable enough to withstand situational influences. After analysing 200 published studies, Hermann described HADS as a “reliable and valid instrument for assessing anxiety and depression” (p. 32). HADS has already been used in a number of studies involving tinnitus sufferers (e.g. Andersson et al. 2003; Zöger et al., 2004). In the former, HADS was determined to produce ‘valid and meaningful data’ (p 259) over the internet, and in the latter, it was suggested that HADS was at its best detecting depression in tinnitus sufferers.

Stroop Paradigm: Based on the original experiments by Stroop (1935, cited Küper & Heil, 2012), this variant contained 150 items presented in lowercase Tahoma font (size 48); 50 being neutral (e.g. a line of four to six X’s), 50 congruent (e.g. the word “green” written in green font), and 50 incongruent (e.g. the word “green” written in red font). Stimuli were presented in one randomized block of 150 trials, with an orientating focus point (150ms) present at the start of each trial. Each stimulus then remained onscreen until participants responded to the font colour in which the stimulus was presented by pressing the corresponding coloured button in front of them: blue, green, red or yellow. On average, the task took three minutes to complete.

Vienna Determination Task (VDT): Previously, Petru et al. (2005) used the VDT to investigate the effects of night shifts on cognitive and psychomotor performance. Furthermore, Karner (2000; cited Petru et al.) used the VDT to illustrate the effects of driving while under the influence of alcohol, or specifically, the delay to reaction time caused by alcohol consumption. Others bodies of work link VDT scores with the ability to drive and the risk of car accidents (e.g. Karner & Neuwirth, 2002; cited Petru et al., 2005) and the effects of methadone maintenance therapy on attention and hand-eye coordination (Specka et al., 2000). This variant displayed ten black-bordered white squares on a white background, arrayed in two horizontal rows of five. Each trial consisted of a square being temporarily by filled with one of five different colours: namely black, blue, green, yellow or red. Participants were required to quickly press the corresponding coloured button to score a correct answer. Regardless of the speed of participant response, the coloured square would remain constant for 1250msecs before being superseded by the next trial, with a different random square now coloured and another participant response required. Note that the VDT was specifically set up in such a way as to ensure that the same square would not display the same colour two trials in a row. There were 48 trials in total, with the whole task lasting one minute. This rapid series of trials was designed to be challenging, as suggested by earlier research (e.g. Hallam et al., 2004; Stephens et al., 2007). The VDT did not record latency, instead recording each response as one of three different categories. Answering correctly within the time limit resulted in a ‘correct’ response. Answering correctly but only after the next trial was displaying would result in that trial being categorised as ‘delayed’ (e.g. pressing red but only after the red square had been replaced by a blue one elsewhere). A wrong answer or a lack of answer within the time limit was categorised as an ‘error’.

Procedure

Control participants were asked to confirm that they knew what tinnitus was, and to confirm that they did not have it. They were also asked to view a copy of the STSS and to confirm the questions were not relevant, and that they would score zero. No member of the control group was subsequently identified as being an unwitting tinnitus sufferer. Volunteering tinnitus sufferers were simply asked to complete the STSS, before all participants were asked to complete both HADS subscales (HADS-A adn HADS-D). Participants then attempted the Stroop Paradigm and the VDT in counter-balanced order. The purpose of the experiment was explained with questions answered when required. No participants chose to withdraw, either then or at a later date. Ethical Approval for this study was granted by the Leeds Trinity University (formerly Leeds Trinity University College) Ethics Panel.

Results

Questionnaires

All controls scored zero on the STSS, whereas the tinnitus group provided a mean score of 7.06 (sd. = 2.38). Three out of thirty-three (9%) tinnitus sufferers reported a score of twelve, with no participant scoring more than this. If we consider the definition of Halford and Andersson (1991a), the majority of the sample was reporting low/ moderate tinnitus distress.

HADS-A returned scores of 6.00 (sd. = 2.48) for the control group and 7.18 (sd. = 4.04) for the tinnitus group. HADS-D scores were 2.73 (sd. = 2.15) for controls and 3.52 (sd. = 2.85) for tinnitus sufferers respectively. Scores for both groups were thus in the normal range. A two-way MANOVA investigated possible significant differences anyway, with the IV being group membership (control/tinnitus) and the DVs being the HADS-A and HADS-D subscales respectively. No significant main effect of group membership was found for either Anxiety [$F(1, 64) = 2.05$; $p = 0.157$ns.] or Depression [$F(1, 64) = 1.60$; $p = 0.210$ns.]. These results further support the notion of a tinnitus sample that had successfully habituated.

Stroop Paradigm

As stated previously, the Stroop task contained three different types of presented stimuli (neutral/congruent/incongruent). Reaction times and errors made were recorded for both groups and in each case, 2x3 mixed ANOVAs (group x stimulus) were utilised.

Stroop Paradigm (Reaction Time): Mean reaction times for correct responses were measured in milliseconds and for the control group, these were as follows: neutral (853.61msecs; sd. 154.34), congruent (838.04msecs; sd. 153.82) and incongruent (986.91msecs; sd. 224.67).

For the tinnitus sample, the following means were observed: neutral (986.75msecs; sd. 267.45), congruent (966.45msecs; sd. 274.03) and incongruent (1118.79msecs; sd. 339.77). The 2x3 mixed ANOVA indicated a significant main effect of group membership on reaction time [F (1, 64) = 4.97; p = 0.029], with tinnitus sufferers having significantly slower latencies. In addition, there was a significant main effect of stimulus [F (2, 128) = 18.04; p = 0.000]. A Least Significant Differences (LSD) post hoc indicated significant differences between all three stimulus types, with congruent stimuli response times quicker than neutral stimuli which were in turn significantly quicker than responses to incongruent stimuli. That the latter was true is indicative that the Stroop Paradigm was working as expected. There was no significant interaction.

Stroop Paradigm (Error Rate): Overall error rates were low, and any interpretation of this data must be considered with this in mind. However, mean error rates for the control group were as follows: neutral (0.55, sd. = 0.794), congruent (0.45, sd. = 0.86), and incongruent (1.15, sd. = 1.27). For the tinnitus sufferers they were: neutral (0.58, sd. = 0.86), congruent (0.21, sd. = 0.415), and incongruent (2.48, sd. = 3.38). The 2x3 mixed ANOVA did not find a significant main effect of group membership [F (1, 64) = 2.29; p = 0.135 ns.] but there was a significant main effect of stimulus type [F (2, 128) = 18.04; p = 0.000]. Again, a LSD post hoc was utilised, with the only non-significant difference being that between neutral and congruent stimuli (p = 0.053ns.) Finally, a significant interaction was observed [F (2, 128) = 5.00; p = 0.008] and this is illustrated in Figure One. As can be seen, most errors are made by tinnitus sufferers in the harder, incongruent condition.

FIGURE ONE NEAR HERE

Vienna Determination Task (VDT)

Out of 48 VDT trials, the control group got 36.21 trials correct (s.d. 8.83) as well as making 4.82 delayed responses (s.d. 6.05) and 6.97 errors (s.d. 5.19). Tinnitus sufferers made 26.79 correct responses (s.d. 10.28) as well as 10.64 delayed responses (s.d. 6.40) and 9.85 errors (s.d. 6.24). A third 2x3 mixed ANOVA (Group x VDT Response) saw a significant main effect of group [$F(1, 64) = 5.91$; $p = 0.018$], a significant main effect of VDT Response [$F(1, 64) = 151.93$; $p = 0.000$] and most importantly, a significant interaction [$F(2, 128) = 13.56$; $p = 0.000$]. These results are illustrated in Figure Two, where it can be seen that the controls were more likely to be correct [$t(64) = 4.08$; $p = 0.000$] while the tinnitus group tended towards a delayed – correct – response [$t(64) = -3.80$; $p = 0.000$] and made more errors [$t(64) = -2.04$; $p = 0.046$].

FIGURE TWO NEAR HERE

Correlations

The results thus far indicate that in the absence of significantly different anxiety/depression levels and with no differences in age, tinnitus sufferers have reduced performance on both the Stroop Paradigm and the VDT. However, these performance decrements are also accompanied by larger standard deviations so it is prudent to consider whether increasing tinnitus distress results in greater performance reductions. After considering the ANOVA findings, it was decided to correlate STSS scores with variables where the presence of tinnitus would appear to have mattered. Significant correlations were found between STSS scores and incongruent Stroop reaction times [$r(66) = 0.255$; $p = 0.039$*], as well as the number of errors made in incongruent Stroop trials [$r(66) = 0.381$; $p = 0.002$**]. The premise that severe tinnitus may hinder cognitive performance more than moderate tinnitus is further supported by a positive correlation between STSS scores and the number of correct VDT responses [$r(66) = -0.438$; $p = 0.000$**], and by a strong negative correlation between the STSS and VDT errors [r (66) = 0.349; p = 0.004**]. In other words, lower STSS scores would seem to increase the likelihood of more correct VDT trials and predict a better performance overall. Furthermore, since STSS scores correlated positively and significantly with HADS-A [r (66) = 0.275; p = 0.026*] and HADS-D [r (66) = 0.254; p = 0.040*], it was decided to investigate correlations between the HADS subscales and incongruent Stroop RT, incongruent Stroop errors, VDT correct responses and VDT errors. For HADS-D only the correlation with VDT errors approached significance [r (66) = 0.234; p = 0.056ns.]. There were no significant correlations between the four performance measures and HADS-A. However, as stated previously, Zigmond & Snaith (1983) have described HADS scores of eight or above as ‘borderline and scores of eleven and above as ‘dysfunctional’. If we only consider participants with dysfunctional HADS scores then only two participants scored ≥11 on HADS-D and sample size was too small to be meaningful. Of greater relevance are the nine participants scoring ≥ 11 on HADS-A (two controls and seven tinnitus sufferers). Here, though sample size was small, a significant correlation between HADS-A and incongruent errors made was found [r (8) = 0.883; p = 0.004**]. These figures hint at an effect of clinical anxiety on task performance irrespective of tinnitus, and even though there were only three severe tinnitus sufferers in the sample, there is the possibility that these two factors could combine and enhance performance decrement.

Discussion

A strength of this study is that unlike much of the tinnitus literature (**e.g. Name, Year**), our sample was purely made up of participants not seeking help for the condition. As such, it could be argued that this sample is more representative of sufferers as a whole. In this context, the confirmation that the tinnitus sample was reporting low/moderate tinnitus severity was unsurprising. Of interest is the fact that the cohort as a whole was neither significantly more anxious nor depressed than the control group. This is important and will be referred to again later.

The results of the Stroop Paradigm showed that tinnitus sufferers were consistently slower to react to individual trials and that they made nearly three times as many errors in the incongruent condition (roughly 6% of incongruent trials). This is in line with the findings of previous studies (e.g. Hallam et al.,2004; Rossiter et al., 2006; & Stevens et al., 2007) where tinnitus-inspired cognitive decrements tended to surface in the hardest tasks.

Results of the VDT were also of interest, the tinnitus group making significantly more errors ($p=0.046$). Most important was the finding that tinnitus sufferers made less 'correct' responses and more 'delayed' responses. In other words, they found it harder to respond correctly to a rapid series of trials without falling behind. The challenging nature of the VDT is that participants need to be swift, and thinking back to the concept of finite cognitive resources (e.g. Kahneman, 1973), central processing of the tinnitus sensation ties up resources that would otherwise be allocated to the VDT, and indeed, to the Stroop Paradigm. This supports the work of Mühlnickel et al. (1998) and Kröner-Herwig et al. (2000) who both stated that inappropriate allocation of finite attentional resources to monitor a tinnitus sensation interferes with and hinders parallel cognitive performance. The significant positive correlations between STSS scores and certain measures of task performance conform to this hypothesis. Participants with tinnitus did less well than the control group, and the more intrusive they felt their tinnitus to be, the more their performance was affected. This sits well with Rossiter et al. (2006) who noted that if people of moderate tinnitus were encountering concentration difficulties, then 'stronger effects may be observed in people with severe tinnitus and possibly higher levels of anxiety and depression' (p. 158). In addition, Andersson et al. (2003) found their measure of tinnitus annoyance correlated with the HADS-A and HADS-D subscales. Here, this finding was replicated with the STSS. Furthermore, some correlations hint at both anxiety and depression having possible effects on task performance. Indeed, much of the tinnitus literature does not clarify whether poor cognitive performance can be explained by the presence of tinnitus, by increased cognitive inefficiency due to anxiety (e.g. Derakshan & Eysenck, 2009) caused by severe tinnitus, that strong co-morbidity with depression could be causing slower reaction times (e.g. Austin, Mitchell & Goodwin, 2002), or even the effects of increasing age (e.g. Tun & Lachman, 2008).

With age comes gradual hearing loss, and this study did not test participants for hearing loss so there is no way of ascertaining whether or not the tinnitus sample differed from the control group in hearing ability. This is a study limitation so our results must be viewed in this context. Such a design is not uncommon to the literature, with neither Hallam et al. (2004) nor Rossiter et al. (2006) collecting full audiometric data, the latter only establishing 'that all participants were able to hear in normal conversation' (p152). Furthermore, there have been studies which link hearing loss to reduced cognitive performance (e.g. Cacciatore et al., 1999; Lin, 2011). However, Cacciatore et al. used a significantly older sample (mean age74.2yrs +/- 6.4 years) when investigating the relationship been hearing loss and general cognitive decline in the elderly, and Lin did not state average age, only that participants were in the 60-69yr age range. Lin did conclude that cognitive performance in participants with a clinically relevant 25dB hearing loss was akin to the performance reduction associated with a seven year age difference. Our study matched the two groups for gender, age, anxiety/depression levels and a lack of hearing aids. We cannot say for certain that no participant had a clinically relevant hearing loss but we are confident that the performance decrements found here can explained by the presence of the tinnitus sensation, particularly when we consider that the above examples concerned participants that were two to three decades older on average. Work such as Cima et al. (2012) emphasis the effectiveness of a multidisciplinary approach to tinnitus treatment and the same can be said for tinnitus research. Psychologists and audiologists need to work together to achieve greater understanding of the effects that even moderate tinnitus can have on cognitive performance. It is suggested that future research can benefit from younger tinnitus populations and from audiometric testing that can eliminate hearing loss as a possible experimental confound.

Overall, as will be explained, our results support Burton et al. (2012), whereby tinnitus was seen to force synaptic change in attentional areas of the forebrain. Our moderate tinnitus group did not perform as well as the matched control group and so the hypothesis is accepted. The very presence of tinnitus would seem to be enough to bring about poorer cognitive performance on tasks requiring general cognitive resources. When cognitive performance is considered, the tinnitus literature tends to compare control groups with people seeking clinical treatment for tinnitus (e. g. Hallam et al., 2004), and while anxiety is sometimes considered as a covariate (e.g. Stevens et al. 2007), sample size is often small. Higher STSS scores correlated with slower response times and more errors, it is notable that only 9% of our tinnitus sample (3 out of 33) would have been classed with severe tinnitus by Halford & Andersson (1991a). Would a larger sample built around this sub-group show further cognitive impairment beyond that found in more moderate tinnitus sufferers? That this may be the case has been hinted at by the parallel correlation between anxiety (HADS-A) and incongruent stroop errors in those eight participants with clinical anxiety levels. With a much larger sample it is likely that some overlap would exist and it is possible that clinically anxious participants with high levels of tinnitus distress would be further affected. If high anxiety levels and tinnitus are both factors in cognitive inefficiency, then it really is unsurprising that tinnitus sufferers tend to report concentration difficulties (e.g. Rizzardo et al., 1998) and that with worsening tinnitus, these problems increase.

It is noticeable that much of the performance decrement in our study took the form of slower reaction times not reduced accuracy, so it could be concluded that the tinnitus sensation interferes more with cognitive efficiency than with cognitive performance – as discussed in Attentional Control Theory (Eysenck & Derakshan, 2011). Here, anxiety impairs the efficiency of the Central Executive, a key component of the working memory model (Baddeley, 1986) and the system that directs and switches attention between stimuli. More specifically, a distinction is made between performance effectiveness and processing efficiency. The former is the degree of success at a given task whereas the latter is a measure of the resources needed to achieve that success. It is suggested that task-irrelevant thoughts due anxiety impair processing efficiency and that greater concentration is then required to apply extra resources to maintain performance (e.g. Eysenck, Payne & Derakshan, 2005). When error rates do become a factor, it is with the most difficult of stimuli (i.e. incongruent stroop stimuli) when participants are at their most stretched. An important component of Attentional Control Theory is the Inhibition Function (Freidman & Miyake, 2004; cited in Eysenck & Derakshan, 2011) whereby task-irrelevant stimuli are prevented from disrupting the performance at hand. There is a growing body of evidence (e.g. Pacheco-Unguetti et al., 2010) supporting the notion that high anxiety interferes with this process, resulting in poor task performance in highly anxious participants. In tinnitus sufferers, this would mean that increased anxiety leads to a greater likelihood of the tinnitus sensation being an effective distraction. Two further points may be raised in support of this idea. Firstly, a reminder that the VDT has been previously used to investigate the effects of shift work and alcohol consumption on cognitive performance (Petru et al., 2005), both factors that are known to hinder executive function (e.g. Christiansen et al., 2013; Horne, 2012). Here, poor performance on the VDT suggests that tinnitus sufferers are struggling with aspects of executive function. Secondly, the stress literature confirms that 'executive and cognitive systems also malfunction as a result of prolonged chronic stress' (Chrousos, 2009; p.378.), and it is well-known than relatively high levels of the stress hormone cortisol can interfere with executive function. It would be of use for future studies in this area to be large enough to compare non-anxious tinnitus sufferers with anxious tinnitus sufferers across a broad battery of cognitive tasks.

To conclude, the results of this study suggest the possibility of widespread concentration issues in non-clinical tinnitus populations that have habituated effectively and are not seeking clinical help. The presence of even moderate tinnitus would appear problematic, especially when considered alongside evidence that the condition brings about synaptic change (Burton et al., 2012). It would be of great interest to ascertain whether severe tinnitus results in further performance issues, and if so, whether the cause is increased severity or factors such as anxiety which are compounding the problem. In their review of Attention Control Theory, Eysenck & Derakshan (2011) suggest a number of different paradigms that produce differences between high anxious and low anxious groups. These include the antisaccade task (e.g. Garner et al., 2009) and task-shifting paradigms (e.g. Johnson, 2009). If anxiety moderates cognitive performance in tinnitus suffers, then from a treatment point of view, effective reduction of anxiety levels (e.g. Andersson et al., 2002) could improve cognitive performance in clinical sufferers.

Acknowledgements and Declaration of Interest

Preliminary findings were presented to the annual British Society of Audiology (BSA) conference in Nottingham, United Kingdom in July, 2011. The authors report no conflict of interest. The authors alone are responsible for the content and writing of the paper.

Figure One: Error Rate for Group x Stroop Stimulus interaction (+/-1SE)

Figure Two: The significant interaction between Group and VDT Response (+/-1SE)

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