Nathan Clarke PhD Thesis – Minor Corrections Overview

In accordance with the 'Changes required for PhD' section of the Examination Report, please see the following summary of how the requested amendments have been implemented within the updated version of the thesis:

1. Critical analysis of theory: Please add further critical evaluation and comparison of literature. The best place for this is probably the overall discussion but it could also be in chapters 4 and 5.

In relation to this point, the following theoretical discussion has been created as a new subsection, Section 6.2.1.1 (pp.222-225):

The results of this thesis and the wider literature may be evaluated and compared to various existing theoretical accounts that consider the relationship between tinnitus and cognitive performance (presented in Sections 1.5.1 and 1.5.2). The theoretical account provided by Mohamad et al. (2016) highlights on the Baddeley model of working memory (Baddeley, 2012). They suggest that cognitive performance detriments associated with having tinnitus represent a failure to stop attending to an 'essentially irrelevant signal'; this is compatible with McKenna's (1997) speculation that tinnitus may 'interfere with the capacity of the phonological loop to store auditory verbal information, in the same way as does for hearing loss'. It has therefore been suggested that having both tinnitus and hearing loss could separately 'add load to the central executive'.

The results of the experimental data analysis presented in Chapters 3 and 4 provide some support for this theoretical perspective. For example, the keep track task was chosen as a measure that was aligned with working memory, and participants in the Non-Distressing Tinnitus group had slightly lower average scores on this compared to the No Tinnitus group, even after adjusting for potential confounds, which could be interpreted as evidence for additional load resulting from the tinnitus signal. However, the updating focus of the keep track task means that a capacity measure of working memory may be a more theoretically relevant measure to provide evidence for this interpretation (Oberauer, 2019). Nonetheless, other authors have reached similar conclusions concerning the potential for additional cognitive load caused by the presence of the tinnitus percept (Khan & Husain, 2020), suggesting that various studies support this result (Rossiter et al., 2006; Stevens et al., 2007).

Similarly, the theoretical perspective of tinnitus causing disruption to the auditory verbal store could also be viewed as supported by some experimental findings from this thesis; for example, participants from the Non-Distressing Tinnitus Group had lower scores on the dual task measure, which was the only task that featured auditory

stimuli. However, the absence of a difference between the Non-Distressing and No Tinnitus groups on the other related working memory task (letter-number sequencing) suggests that no additional load is caused by the presence of a tinnitus signal per se, and supports a theoretical account such as the EDM (Section 5.3), where poorer performance in the associated cognitive system would be a predisposing and contributory aspect in the experience of tinnitus distress.

McKenna at al. (2014) have proposed a theoretical perspective suggesting that tinnitus distress is caused by a conscious process of monitoring, where sustained attention is central to this account and failures of selective attention may be a contributing factor. Various studies have also implicated sustained monitoring and attention (Leong et al., 2020; Lima et al., 2019). Some aspects of the experimental data in this thesis may be interpreted as being consistent with this theoretical account, such as the poorer performance in tasks by the Distressing Tinnitus group; however, it is challenging to explain the improved performance associated with the Non-Distressing Tinnitus group membership from this theoretical perspective (these challenges are discussed in Section 6.3).

The aforementioned observations also present challenges the theoretical account provided by Trevis et al. (2016) in their 'neurocognitive' model. This account suggests that chronic tinnitus is caused by a failure of the Cognitive Control Network (CCN). Various other theoretical perspectives have also implicated attention and related cognitive concepts as a contributory factor to the chronification of tinnitus (Roberts et al., 2013; Sedley et al., 2016), though Trevis and colleagues have provided the most explicit account of a theoretical model (Section 1.5.1.4). However, participants in this EFiT study described in Chapter 3 all had chronic tinnitus, while the data presented in this study demonstrated that those in the Non-Distressing Tinnitus group did not exhibit generalised failures of cognitive control as measured by the battery of core executive function tasks that were presented in Chapter 3. Therefore, a theoretical account of tinnitus that incorporates cognitive performance needs to highlight the central role of tinnitus distress, not the chronification of the percept (i.e., chronic tinnitus can be present without it being a measurable detriment to cognitive performance).

I previously suggested that the neurocognitive model has questionable validity (Section 5.2). In addition to experimental data from this thesis not supporting this model, there is also a theoretical aspect of this criticism that should be considered in future research: chronic tinnitus is not necessarily distressing tinnitus. The majority of people with chronic tinnitus do not report being distressed or having significant concentration difficulties or reporting detriments in cognitive performance. However, it should be noted that the theoretical position presented in the neurocognitive model may

have been influenced by research that has suggested that 'non-help-seeking tinnitus sufferers' have detriments in cognitive performance (Jackson et al., 2014). Furthermore, the neurocognitive model also suggests that cognitive components act as a mechanism for the chronification of tinnitus, meaning it cannot therefore be considered a cognitive model of tinnitus distress per se. This highlights the need to provide an adequate theoretical account for the role of cognition in tinnitus chronification in addition to tinnitus distress. Challenges associated with the incorporation of cognition (specifically attention) into contemporary theoretical accounts of tinnitus initiation, chronification, and distress are further discussed in Section 6.3.

2. THI: please add a section to discuss the scoring and categorisation methods of the THI. Explain how your method differs to the standard, the rationale for using this method and the strengths and limitations of this approach.

The following text has been added to Section 3.3.1.2 to discuss rationale of the thresholds chosen for the THI to assign the study experimental groups (pp.78-79):

Research concerning the validity of the THI shows it to be a unidimensional measure of tinnitus distress (Fackrell et al. in Signorelli and Turjman, 2014, p. 47). Categorisation of the Distressing Tinnitus and Non-Distressing Tinnitus groups was chosen at ≥38 with a clinical descriptor of "Moderate". The clinical descriptors that accompany the Moderate category state that the tinnitus is "noticed in presence of background noise, although daily activities can still be performed". If allocating of participants to groups is solely based on the THI original scoring manual, it could be argued that that distressing tinnitus would be mapped to a clinical descriptor of at least "Severe" tinnitus (i.e., THI score ≥58); the accompanying suggested clinical descriptor for Severe describes this grading of tinnitus as: 'Almost always heard, leads to disturbed sleep patterns and can interfere with daily activities'.

However, given scrutiny of the item content, it should be noted that the clinical descriptors that accompany the numerical thresholds should serve only as a guide and are in no way a strict criteria mapping of distress; for example, despite its descriptor suggesting that Severe tinnitus "leads to disturbed sleep patterns", only 1 of 25 questions present on the THI asks about sleep (Q7). This allows someone to obtain a clinical descriptor of Severe/Catastrophic tinnitus (≥58 points), while answering 'No' to the only question regarding difficulties with sleep. Conversely, someone may have Slight tinnitus (<16), while answering 'Yes' to this question. Furthermore, relying solely on the clinical descriptors would suggest that the presence of a chronic tinnitus percept (as

every participant had) is insufficient to cause distress, which was an assumption I avoided when planning the EFiT study. Therefore the grouping at a Moderate level on a unidimensional measure of tinnitus distress, frequently used within a clinical setting, was considered a pragmatic solution to assigning study groups.

3. Stroop: Please add a short section to discuss the limitations of the interpretation of the inhibition/Stroop results.

The following text has been added to Section 4.4.1 (p.167).

The Stroop task was chosen and suggested to be an appropriate measure to emphasise the core executive function of Inhibition (Diamond, 2013). However, a limitation to the interpretation of the experimental results using the Stroop task concerns the attribution of slower response time to inhibition per se. This is because the incongruent condition of the Stroop task was the sole condition used in analysis. This obfuscates interpretation of the results as a measure of specific interference because the incongruent condition measures both general slowness (i.e., processing speed) and interference. It has been suggested that using the difference between the neutral and incongruent condition should remove factors common to both conditions such as general slowing (Wright, 2017). Therefore is may be argued that general slowing could be responsible instead of an inhibitory effect. However, the interpretation of the results as an inhibitory effect is supported by results from Clarke et al. (2020), which demonstrate that EF-inhibition was poorer across various inhibitory paradigms and analytic methods, including various Stroop paradigms and analyses, with the meta-analysis providing no evidence of a single result driving this finding. Furthermore, the additional measure of interference controlled for output interference within the paradigm administered to all participants, which increases the likely attribution of the differences between groups to an inhibitory mechanism (Murayama et al., 2014). Therefore, the union of results from this measure and previous synthesis and inhibitory paradigms should increase confidence in attributing Stroop findings to an inhibitory mechanism.

4. Significance level: remove and correct p=0.00, add clarity as to what would be significant if a more reasonable alpha (corrected for multiple comparisons at least on each measure or at least a more stringent alpha -0.01, 0.001 is used).

For clarity, tables that contained a p-value of 0.00 or 0.000 (following truncation of the exact value) have been amended to read <0.01 or <0.001 (depending on the significant

figures for that table). The following paragraph has also been added to the Section 3.5.6.4 (p.117):

Bonferroni correction to adjust p-values in relation to tests of between-group differences was discussed in the Section 3.4.3, but was not applied for congruence with previous statistical analyses in this field. Conceptual difficulties related to NHST methodology such as defining a family of tests (Althouse, 2016; Perneger, 1998), and the inclusion of additional inferential support from Bayesian methods, also negated use of correction. However, a more stringent alpha value could have been selected through the application of such a correction or other arbitrary procedures. For example, a 0.01 alpha could have been selected for congruence between Bayes Factors and NHST methods in the wider published psychological literature (Wetzels et al., 2011). If this alpha was applied then additional between-group differences to those already reported would not have been statistically significant: i.e., the number-letter sequencing and RIF for the No Tinnitus and Distressing Tinnitus groups, and the dual task for the Non-Distressing Tinnitus and No Tinnitus group. If alpha of 0.001 was applied, then additional between-group differences to those reported and described at the 0.01 level would not have been statistically significant: i.e., the keep track task for both the No Tinnitus and Distressing Tinnitus groups, and the Non-Distressing Tinnitus and No Tinnitus groups. However, interpretation of the study results and related hypotheses were ultimately informed using a variety of analyses, statistics, and theoretical considerations, in addition to formal NHST and its documented challenges.

5. SCM: In chapter 5 add a critical discussion of limitations and weaknesses.

The following paragraph has also been added to the discussion section of results for Section 5.4 (p.196):

Despite the many benefits of the SCM framework, limitations of this framework should also be considered relative to other modelling options. For example, although SCMs do not require data from every variable within the entire model to be identified and estimate the path of interest (unlike SEMs), SCMs do not provide an overall test of model fit through chi-square statistics and therefore do not provide a test of data fit relative to a null model (Kline, 2016). Though it should be noted that even within an SEM framework, a model exhibiting good fit still has many mathematically equivalent models that support different theoretical accounts (Hershberger & Marcoulides, 2013; Raykov & Penev, 1999).

An additional consideration regarding limitations of the SCM framework concerns the mapping of various competing theoretical accounts, or process models, to the statistical

model of the SCM (McElreath, 2016). For example, although a process model may be specified and evidence derived from its usage in support of a particular theory, there are various other theories and process models that could be correct, specified, and then tested that imply a similar result. However, McElreath (2016) argues that this should be considered an epistemological concern of the scientific method more generally, and the SCM framework and DAGs are at least advantageous in providing a clear, readily-communicable, and explicit means of sharing theoretical assumptions with other researchers.

6. Add a short clear Covid impact statement.

The following text has been added the end of Chapter 6 (p.245):

Covid impact statement: Additional planned experimental work (that aimed to investigate the impact of an artificial tinnitus sound on the cognitive performance of individuals without tinnitus) was impacted by the Covid pandemic. University closures and testing restrictions led to considerable disruption of planned activities and the subsequent abandonment of this line of research. This negated a large amount of related work that I had already completed, including a considerable amount of study planning, material preparation, and successful applications for ethical approval.

In addition to the 'Changes required for PhD' section, various minor alterations to correct minor spelling, missing words, and grammar corrections have also been made to the thesis throughout.