Linköping University | Department of Computer and Informational Science
Bachelor thesis, 18 hp | Cognitive Sciences
Spring term 2019 |LIU-IDA/KOGVET-G--19/029--SE

Unraveling interaction between tinnitus symptoms, cognitive abilities, and mental disorders

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Abstract

Based on the former studies, there is evidence of tinnitus being associated with performance on cognitive ability tests (for example Andersson et al. 2009, Hallam et al. 2004). The topic of my bachelor thesis was to unravel how depression, stress and anxiety connected with tinnitus symptoms are related to cognitive abilities such as verbal fluency, inhibition ability and working memory capacity. In order to fill an existing gap of knowledge, the relationship of different severity of stress caused by tinnitus symptoms as measured with Tinnitus Handicap Inventory (THI) and cognitive abilities and depression and anxiety symptoms was emphasized.

The experiment group was divided into two subgroups, those with lower and higher level of perceived tinnitus severity and the differences in test scores between groups were investigated with one-way analysis of variance. As a result, significant differences between the two tinnitus patient groups were found in the level of performance in inhibition task where participants were asked to give the font color of congruent color - word pair as an answer. It was also studied whether there were correlations between perceived severity of tinnitus symptoms, depression and anxiety symptoms, working memory capacity and inhibition ability. As a result of correlation analysis, this study confirmed the connection between tinnitus symptoms and anxiety and depression symptoms found in previous studies, and a significant correlation was found between THI scores and anxiety symptoms, and THI scores and C inhibition test scores where the participant was asked to name the font color from incongruent color-word pairs. The results of this study suggest that there is a connection between the level of perceived tinnitus severity and the ability to name font color of incongruent color - word pair. The current study found no evidence about the connection between THI scores and other cognitive abilities as well as anxiety and depression symptoms, even though the THI scores correlated with both anxiety symptom scores and with the reaction times of an inhibition task where the participants were asked to point out the font color from incongruent color - word pairs.

Acknowledgement

Working with my thesis was a process which would have been hardly possible without the valuable help of many individuals. First, I would like to thank my supervisor Carine Signoret for insightful comments through the entire thesis work, Örjan Dahlström for familiarizing me with the research topic, and Professor Henrik Danielsson for helping me to find an interesting research topic. Also, I am grateful to Sophie for all of her mental support and for our long study sessions, and to Samu and Sofia for listening my stressed-out monologues at least one time too many. Without them, it would have taken a longer time for me to finish my thesis. Finally, I am thankful for my family and all of my friends who in different ways supported me.

Linköping in July 2017

Sini Alhola

Contents

List of Abbreviations

Abbreviation	Meaning
CFQ	Cognitive Failures Questionnaire
HADS	Hospital Anxiety Depression Scale
PTA Left	Pure tone audiometry from left ear
PTA Right	Pure tone audiometry from right ear
RST	Reading Span Test
SRB:1	Synonyms, Reasoning, Block Test (Synonyms)
Stroop A - E Scores	Inhibition scores of A, B, and C tests, and calculated D and E scores
Stroop A% - E% Scores	Percentages of correct responses of A, B, C, D, and E scores
THI	Tinnitus Handicap Inventory
TRQ	Tinnitus Reaction Questionnaire
WAIS-IV Block Design	Wechsler Adult Intelligence Scale (Fourth Edition) Block design – sub-test
WAIS-IV Word	Wechsler Adult Intelligence Scale (Fourth Edition) Word – sub-test

1 Introduction

Tinnitus in its varying degrees of severity is a common issue among humans (McCormack et al. 2016). Depending on the method of measurement, a prevalence of tinnitus symptoms has been estimated being somewhere between 5.1% and 41.7% of total worldwide population (McCormack et al. 2016). According to a short form of definition, the tinnitus symptoms refer to a non-speech auditory perception without an outlying source.

From the perspective of cognitive science, and especially of cognitive hearing science, tinnitus severity is a highly relevant research topic. This is due to evidence of tinnitus being associated with hearing impairment and performance on tests measuring cognitive abilities (for example Andersson et al. 2009, Hallam et al. 2004).

This study emphasizes the topic of tinnitus by concentrating on the stress caused by the symptoms as measured with Tinnitus Handicap Inventory (THI). In Swedish population, there are only a few former studies made with this perspective. What is more, this study seeks to unravel the connection between the tinnitus symptom related stress and other factors, such as certain cognitive abilities, depression and anxiety symptoms, which has been associated with each other in previous studies.

As the topic for my bachelor's thesis in Cognitive Science program, I studied the relationship between cognitive abilities, depression and anxiety symptoms and the perceived severity of tinnitus symptoms. In addition, I investigated the association between the severity of tinnitus symptoms, depression and anxiety symptoms, working memory capacity and inhibition ability. The study was done as a part of the larger tinnitus related experiment conducted at Linköping University. My study uses the material from two first steps of the study, the internet screening (THI and HADS (Hospital Anxiety Depression Scale) scores) and behavioral testing (cognitive ability test scores).

In this study, I concentrated on the following research questions:

- How the severity of tinnitus symptoms is related to cognitive abilities such as verbal fluency, inhibition ability and working memory capacity?

- Are there differences in cognitive abilities or depression and anxiety symptoms between groups with lower versus higher level of perceived severity of tinnitus symptoms?

2 Theory

2.1 Tinnitus symptoms

Tinnitus in its various forms of severity is a common issue among the adult population in Sweden (Andersson et al. 2009). According to the most common type of definition, tinnitus refers to a wide range of sounds that are heard without the presence of an external source. These sounds can be for instance hissing or ringing by nature. An excluding criterion for the tinnitus is, however, the absence of semantical information (Andersson et al. 2009), distinguishing tinnitus symptoms from auditory hallucinations. It is estimated that about 10 % of world population has tinnitus symptoms, yet there is a high level of variance within the severity of the symptoms (Langguth et al. 2013).

2.1.1 Physiological abnormalities associated with the onset of tinnitus symptoms

Before starting to describe the structural differences associated with tinnitus, I am going to give a brief description about the sound perception of human auditory system. The organs in the external ear and middle ear are responsible for collecting the sound waves and conveying them into the inner ear where they are transformed into neural signals (Salvi, 2016). In the inner ear, the auditory signals are perceived via the stimulus of hair cells, the specified sensory receptors that are located in the organ of Corti inside of cochlea. The stimulation of hair cells, in turn, triggers the activation of auditory nerve (Salvi, 2016).

The onset of tinnitus symptoms is most often followed by a trauma (such as noise trauma, hearing loss or presbycusis, an age-related hearing loss) resulting cochlear lesions (Langguth et al. 2013). The noise trauma refers to an inner ear injury caused either by a short-term high-frequency noise or by a long-term exposure to a noise with lower frequency. The cochlear lesions result an abnormal stimulation of hair cells and hence an abnormal activation of the auditory nerve, which is perceived as tinnitus (Langguth et al. 2013). Additional, yet more uncommon types of abnormalities associated with the onset of tinnitus symptoms are structural changes in auditory nerve, resulting abnormal neural activation (Langguth et al. 2013).

There is a high comorbidity between tinnitus and hearing loss (26 dB or greater hearing threshold, using the average value of a pure tone audiometry (PTA) audiogram results of frequencies 500, 1000, 2000 and 4000 Hz. (WHO, 2017)), as well as between tinnitus and presbycusis. Because of these comorbidities, ages of participants as well as audiometric test results were included in the test data. A PTA was chosen as a method to gain audiometric data because it is the most commonly used clinical way for evaluating hearing thresholds (Langguth et al. 2013).

2.2 Tinnitus severity

The onset of tinnitus symptoms can be resulted by diverse physiological abnormalities. Because of this, it can be problematic to rely solely on physiological assessments when studying the tinnitus symptoms. This leads us to the topic of plausible perspectives on studying tinnitus. As mentioned in the introduction chapter, the current study focuses on the subjectively experienced effects caused by symptoms. The chosen method to measure the severity of tinnitus symptoms is Tinnitus Handicap Inventory (THI) (Tinnitus Handicap Inventory, 2012). The THI is designed to analyze the cognitive and emotional difficulties experienced by tinnitus patients (Frank et al. 2015). This self-evaluation survey of 25 questions in total consists three types of questions based on the nature of perceived difficulties, functional (for example "Because of your tinnitus is it difficult for you to concentrate? "), emotional (for example "Does your tinnitus make you angry?") and catastrophic (for example "Do you feel as though you cannot escape your tinnitus?") (Newman et al. 1996). A full list of survey questions is included in Appendix A. The choice of this particular survey about tinnitus severity was based on the former, promising results about its reliability and validity, studied for example with confirmatory factor analysis (Frank et al. 2015).

2.3 Tinnitus and cognitive abilities

Previous studies have shown some evidence about the connection between tinnitus symptoms and certain types of cognitive abilities. For example in the study by Andersson et al. (2002) it was found that the tinnitus group, whose tinnitus symptoms were measured using the a pure tone audiometry (PTA) and the distress caused by the symptoms was measured using the Tinnitus Reaction Questionnaire (TRQ), received overall lower scores in digit-symbol test compared to control group that did not report having tinnitus symptoms. The used task, digit-symbol test, measures selective attention, visuomotor speed and set shifting (Andersson et al. 2002). Also, in the experiment run by Hallam et al. (2004), tinnitus patients reported more cognitive failures in a self-evaluation survey (Cognitive Failures Questionnaire - CFQ) as opposed to the control group.

2.3.1 Visuo-spatial ability and verbal comprehension

The previous studies about the connection between tinnitus and verbal aspects of intelligence have given contradictory results. For instance, Andersson et al. (2000) found evidence about tinnitus patient's difficulties with the vocabulary test compared to the control group. Also, an experiment by Hallam et al. (2004) resulted lower scores among tinnitus group in verbal fluency task. However, Andersson et al. (2009) found no evidence about lower test scores of

verbal abilities among tinnitus patients when using Swedish test of synonym production, Synonymer (SRB:1) as a method.

Andersson and McKenna (2006) hypothesized that the impact of tinnitus in cognitive functions resembles the U-letter; the impact is high in both relatively undemanding and demanding tasks yet low in moderately demanding tasks. The hypothesis goes well together with contradictory test results and serves as a motivation to test tinnitus patients with different types of intelligence related tests to unravel how the tests results of different levels of difficulty vary from each other. The verbal comprehension task (WAIS Word) used in this study requires the usage of a wide range of verbal abilities, such as the verbal reasoning and concept formation (Lichtenberger & Kaufman, 2009). This requires, among other things, good verbal understanding and large size of the lexicon. Since this specific type of verbal intelligence test is considered demanding (Lichtenberger & Kaufman, 2009), tinnitus symptoms are expected influencing it.

Unlike with many other WAIS-IV categories, there are not many previous studies about the connection of tinnitus and nonverbal abilities. Since there is evidence about tinnitus symptoms affecting on various traits of cognitive abilities (for example Andersson et al. 2002; Hallam et al. 2004), it seems plausible to fill this gap of knowledge by looking into the category of nonverbal abilities as well. Based on previous studies, the test used in this study, Block Design test has found to be heavily correlated with WAIS total score, indicating the test's ability to measure nonverbal aspects (Wechsler, 1981). Also, related to the study by Andersson and McKenna (2006), tinnitus symptoms are expected to have an effect on the results of Block Design test because the test has been considered demanding for example by Lichtenberger & Kaufman (2009). The authors considered the Block Design test demanding mainly because it requires quick visual-motor coordination (Lichtenberger & Kaufman, 2009).

2.3.2 Working memory

Much like what is the case with visuo-spatial ability test and verbal comprehension tests, the previous results about the connection between tinnitus and working memory are contradictory. One of the most convincing pieces of evidence about this connection is from the study by Rossiter et al. (2006) where Reading Span Test (RST) was used as a method. In RST, the participants are asked to read an increasing number of sentences in each turn, after which they are asked to recall the last word of each sentence. As a result, the tinnitus patients scored significantly lower (were able to recall fewer words) compared to the control group (Rossiter et al. 2006). Interestingly, it was also found that there was no correlation between RST scores and anxiety scale (STAI, State-Trait Anxiety Inventory) scores.

However, there has been previous experiments where the support for the connection has not been found. For example, Hallam et al. (2004) run an experiment that was directly targeted to study the connection between tinnitus and the function of the phonological loop. According to Baddeley (1992) the phonological loop is the part of working memory system that stores auditory verbal information. The experiment by Hallam et al. (2004) found no support that would have indicated differences in the function of the phonological loop neither in the

tinnitus group nor in the control group. One of the possible explanations for the results is that tinnitus symptoms have an effect on other aspects of working memory than on phonological loop. Based on the previous study results by Hallam et al. (2004) and Rossiter et al. (2006), it seems plausible to use the RST as a method to further unravel the connection between tinnitus and working memory, as well as their connection to other variables.

2.3.3 Inhibition

In the experiment about the function of phonological loop (Hallam et al. 2004), which was mentioned in the previous section, the research tasks were performed both in single task and dual-task conditions. In the study, the tinnitus group performed overall worse than the control group and the second experiment group of hearing impaired patients with a dual task of inhibition, an attention guiding task and a verbal fluency task. According to the authors, the focus of this dual task lies on the processes of sharing, guiding and inhibiting attention. This may suggest that the tinnitus group's lower performance in cognitive tasks could be connected with lowered ability to manage attentional processes (Hallam et al. 2004).

In their studies, Andersson et al. (2000) found a link between longer response times in inhibition tasks (Stroop test) and tinnitus. The follow-up study by some of the same authors (Andersson et al. 2009) sought to further establish the link between tinnitus symptoms and lower inhibition ability. In the essence, this was done via intermittent masking of tinnitus when performing cognitive ability tests. The group's hypothesis was that the inhibition required to cope with tinnitus symptoms resulted in both lower cognitive ability test results and lower Stroop test results. However, they found no evidence to support their hypothesis, which led them to discuss about alternative explanations. It was, for example, suggested by authors that the lower performance of working memory test in the tinnitus patient group might be a hidden variable, explaining the connection between tinnitus symptoms, cognitive abilities and inhibition abilities (Andersson et al. 2009). In the light of all these results, it was decided to test whether the evidence about the lower inhibition ability among tinnitus patients could be found in this study. The same method of testing (Stroop test) as in the study by Andersson et al. (2009) was used. The results of this study are expected to shed more light on the interaction between tinnitus symptoms, cognitive abilities and inhibition abilities suggested by both Andersson et al. (2009) and Hallam et al. (2004).

2.4 Depression and Anxiety symptoms

Based on previous studies, depression and anxiety symptoms have found to occur in high prevalence with tinnitus symptoms among tinnitus patients (see for example Cho et al. 2013). According to the American Psychiatric Association (2013), depression refers to a combination of symptoms such as depressed mood or irritable, constantly decreased interest or pleasure in

most activities, constant feeling of fatigue, lowered ability to concentrate or to make decisions.

Anxiety symptoms, in turn refer to excessive feelings of fear and anxiety (American Psychiatric Association, 2013). As a distinguishing factor between fear and anxiety, anxiety is defined as a reaction to threat, that, unlike fear, is temporally located in the future (American Psychiatric Association, 2013). Based on a meta-analysis by Moran (2016), there is a well-established connection between anxiety symptoms and lowered working memory capacity. In the results of a study by Mier et al. (2017) no evidence was found to indicate the connection between anxiety symptoms and (non-emotional) Stroop scores in participants of general population.

Both anxiety and depression symptoms are most commonly measured with the help of self-evaluation surveys. In the case of this study, a Hospital Anxiety Depression Scale (HADS) was used. According to previous studies such as the one by Myklentun et al. (2001) HADS has been shown to be a valid tool to measure anxiety and depression symptoms, providing coherent results with other self-evaluation tools in both clinical and general populations. Moreover, in a previous study by Andersson et al. (2003), HADS was successfully used as a method to study anxiety and depression symptoms of tinnitus patients among the Swedish population.

2.5 About this study

To summarize, this study is focusing on the following research questions: Are there statistically significant differences in HADS scores, WAIS Word and Block Design scores, Stroop test scores, and Reading Span Test scores by perceived severity of tinnitus symptoms measured with THI scores? And is there a relationship between severity of tinnitus symptoms, depression and anxiety symptoms, working memory capacity and inhibition ability? In order to avoid the confounding variables discussed in section 2.1.1 it was also studied whether there are statistically significant differences in age and hearing loss by perceived severity of tinnitus symptoms.

To answer the former research question, the one-way analysis of variance was conducted using HADS scores, WAIS Word and Block Design scores, Stroop test scores, Reading Span Test scores, pure tone audiometry results and ages as dependent variables, and classification to participant groups which was done based on THI scores as independent variable. The study was conducted in a quasi-experimental design because of the lack of random assignment of participants on different participant groups (control group, a group with lower level of tinnitus severity and a group with higher level of tinnitus severity). The distribution on tinnitus group into two separate groups was motivated by wish to study whether they differed from each other when it comes to the results of visuo-spatial ability test, verbal comprehension test, working memory test, inhibition task and Hospital Anxiety and Depression Scale. To my knowledge, there is no former research about the topic. THI scores were added in the analysis

as a dependent variable in order to validate that there are significant differences between participant groups.

Based on the former results reviewed in this section, it was expected to see significant differences in participant groups when it comes to cognitive ability test results as well as HADS scores. To specify, the experiment groups (groups with lower and higher level of tinnitus severity) were expected to have lower level of performance in cognitive ability tests compared with the control group. Likewise, it was expected for the tinnitus groups to receive higher scores from Hospital Anxiety Depression Scale (HADS), indicating more prevalent psychological distress. These expectations were, among other theories discussed above, based on the study results by Andersson & McKenna (2006). According to their findings, the effect of tinnitus on cognitive processing was greater with relatively undemanding and demanding processing as opposed to moderately demanding tasks. The absence of significant differences as a result could, according to this study, be hence explained the tasks being moderately demanding.

The latter research question, in turn, was studied with a correlation analysis. Based on results by for example Cho et al. (2013), Moran (2016), Andersson et al. (2009) and Hallam et al. (2004), the working memory capacity and inhibition ability were expected to be correlated with both perceived severity of tinnitus symptoms and depression and anxiety symptoms. If the results from correlation analysis turn out to be non-significant, certain alternative explanations should be discussed. These explanations include for example the small sample size of this experiment as well as the possibility that RST and Stroop test may not be optimal methods to study working memory capacity and inhibition ability in tinnitus patients, despite of the former promising results.

3 Method

3.1 Participants

The ages of participants ranged from 19 to 67 (mean = 37.6, SD = 14.5). The participants included 33 persons in total (14 women), 24 with tinnitus symptoms and 9 without it. All of the participants had Swedish as their native language. For selecting the participants for the study, there were several exclusion criteria, such as neurological problems and problems with mental health, the uptake of medicines that could influence cognitive performance, and the medical condition called hyperacusis. Hyperacusis, a condition where the sound sensitivity towards certain volumes or frequencies has increased (Salvi, 2016), was considered as an excluding criterion in order to draw general conclusions about audiometric test results and to compare the results of different participants. Since an initial plan was to include the neurophysiological activity patterns as a part of the research material and certain exclusion criteria were introduced to avoid non-variable related anomalies in brain imaging data. Because of this, the participants who were left-handed, had a severe visual impairment or had metal implants attached in their body were excluded.

3.2 Materials

3.2.1 Self-evaluation surveys

Tinnitus Handicap Inventory (THI)

Participants were asked to fill in the 25 questions of THI survey in order to measure the perceived severity of their tinnitus symptoms. THI survey was designed to measure negative psychological effects of tinnitus with 25 questions (see the list on appendix A) that are divided into three categories, functional, emotional and catastrophic (Newman et al. 1996). The participants were asked to give their answer to each question on 3-point scale (Yes, Sometimes, No). There are no reversed items in the questionnaire. Based on the scores gained from the survey (0-100) the survey measures a THI grade, ranging from 1 (Slight) to 5 (Catastrophic) (Newman et al. 1996) (see Appendix A for more information).

In this study, the experiment group was divided by median into two groups of 12 participants based on the THI score. These tinnitus groups with lower and higher THI scores (scores of 0-20 and 20-56) were formed in order to have two groups with equal amounts of participants. On the larger scale, the focus was to avoid the bias in statistical analysis caused by varying sample sizes. Therefore, the border values (THI scores) of groups were artificially formed and were not based on the classification of THI scale.

Hospital Anxiety Depression Scale (HADS)

Participants were asked to fill in HADS survey in order to measure anxiety and depression symptoms. The survey is divided into two sections, one measuring anxiety (seven questions) and one measuring depression (seven questions). The results from each section range from Normal (0-7) to Abnormal (11-21). In the analysis, two HADS scores were used, taking into account the scores of anxiety and depression sections.

3.2.2 Cognitive ability tests

Visuo-spatial ability test and verbal comprehension test

The WAIS test seeks to measure overall cognitive abilities of adults (Lichtenberger & Kaufman, 2009). Two subtests of WAIS-IV, vocabulary test and visuo-spatial ability test were used. The verbal comprehension test is a subtest of Verbal Comprehension Index (VCI) whereas the visuo-spatial comprehension test (Block Design test) is a part of Perceptual Reasoning Index (PRI) (Lichtenberger & Kaufman, 2009).

Verbal comprehension test

Verbal comprehension test was used to measure verbal abilities of the participants, such as verbal understanding and the size of the lexicon (Wechsler, 2008). In this test, the participants were asked to define words orally presented by the instructor. The participants gained scores

based on the total amount of correctly named/defined item and possible scores ranged from 0 to 57.

Block Design test
Block Design test is used to measure non-verbal intelligence, namely visuo-spatial abilities (Wechsler, 2008). The participant's task was to replicate the pattern shown in the form of a picture by using red and white blocks. Some task had to be performed within a time limit (either 60 seconds or 120 seconds) and the score depended on how fast the task is performed. The possible total score ranges from 0 to 66.

Reading Span test (RST)

A standardized Swedish version of RST (Rönnberg et al. 1989) was used to measure working memory capacity (Daneman & Carpenter, 1980). Participants were asked to read aloud increasing number of sentences in each turn, after which they were asked to recall the last word of each sentence. The result of RST consists the total amount of correctly recalled words (maximum 28 words).

Stroop task

A standardized version of Stroop task was used to measure participant's ability of inhibition. In the test, the participants were asked to name the color of the word, ignoring what is actually written (Jensen, 1965). In the incongruent task, the font colors of the words were not corresponding with the written names of the color, whereas in the congruent task the written name of the color and font color were identical (for example blue written in blue. The program that was used to run the test was called SuperLab™ 2.0 stimulus presentation software (Cedrus Corp, San Pedro, CA). In the part A, the neutral physical task, the participants were asked to identify colors presented in a square on the screen (Jensen, 1965). In the part B, the task was to give the font color of congruent color - word pair as an answer. In the task C, in turn, the participants were asked to point out the font color from incongruent pairs. The reaction times (in milliseconds) as well as the percentages of correct responses of tasks A, B and C to give a correct answer were reported as results (Jensen, 1965). The calculated score D seeks to illustrate non-speed related individual differences in distinguishing ability, whereas the score E, so-called "interference factor" illustrates the increment of difficulty caused by incongruent size-value pair in the task C.

3.2.3 Audiometric test results

Based on the previous studies such as Langguth et al. (2013) and Andersson et al. (2009), there is evidence about the high comorbidity between tinnitus and hearing deficiency. Hence, the idea behind the audiometric testing in this study was to measure, with pure tone audiometry (PTA), whether participants with hearing deficiency were present in some of the participant groups. In the light of the previous findings, the groups with tinnitus patients were expected to higher number of participants with hearing impairments. In the test, participants were asked softest sound audible to them. The used sound frequencies to measure audible thresholds ranged from 200 to 8000 Hz (WHO, 2017). Audiometric testing was performed to

both left and right ears. The audiometric test results were mean values of frequencies 1000 and 4000 Hz to illustrate the participant's thresholds on average. These specific frequencies were chosen since they are located in the typical range of human speech (Langguth et al. 2013). From now on, I will refer to audiometric test results as PTAright (right ear) and PTAleft (left ear).

3.3 Analysis

3.3.1 Procedure

The data used in statistical analysis was received from an experiment that is run in Linköping University. The experiment consisted three parts in total, an initial internet screening, a behavioral testing and an fMRI study. The first part included screening for exclusion criteria, as well as the THI and HADS self-evaluation surveys. The second part, behavioral testing, included the cognitive ability tests (RST, Stroop task, Block design test and Verbal comprehension test) and the audiometric testing. In the last part, participants took an n-back test during the brain imaging.

The long-term plan is to couple the behavioral data with neurophysiological activity patterns from brain imaging to further unravel their relationships and, hence, use data from all three parts of the experiment in my thesis. However, due to the time limit of this study, the data from brain imaging was not processed early enough to be attached in the materials. The recordings of brain imaging from the same participants were performed, and I was personally involved in one of them.

The participants were recruited by an online advertisement. In the advertisement, a reward of 500 kronor was offered to participants. The recruiting took time from the end of April 2015 to the end of May 2015. The volunteering prospective participants were sent the link to the internet screening. 18 participants in total were excluded based on the internet survey. In the next phase, behavioral testing, a member from the research group met participants in person and they were asked to take the cognitive tests used in this study. The results from audiometric test were also included to data in this phase.

3.3.2 Prerequisites of statistical analysis

As instructed by Field (2013), one important factor to unravel before beginning to run statistical analysis in general is to figure out whether all the variables are normally distributed, since this affects on choosing the suitable statistical test. Hence, the Kolmogorov-Smirnov test was run and the skewness and kurtosis scores for the variables were calculated. As a result, it was found that the HADS depression scores (skewness of 1.50 (SE = 0.41), kurtosis of 1.70 (SE = 0.80), $D(33) = 0.219$, $p < 0.01$)) did not pass the normal distribution test , yet the HADS anxiety scores and the cognitive ability test scores were approximately normally distributed. Because of these deviations from normal distribution, the Spearman's correlation analysis was

chosen as method for correlation analysis (Field, 2013). One-way analysis of variance was chosen even though normality is one of its test prerequisites. This was done since, according to Field (2013), ANOVA tests are not sensitive to slight deviations of normality. Furthermore, based on the frequency histograms, it seemed like those deviations from normal distribution were moderate.

In order to test the equality of variances, which is a prerequisite of both one-way analysis of variance and Tukey's B, the chosen post-hoc test, the Levene's homoscedasticity test was run. The method of post-hoc analysis was chosen to inspect which ones of the groups differed from each other. The test hence supplements the one-way analysis of variance, which is designed to identify significant differences between any of the groups. The Levene's homoscedasticity test results implied that, overall, the assumptions of equal variances of variance analysis were met.

3.3.3 Statistical analysis

All the statistical analysis involved in this study was done using IBM SPSS Statistics 24 program. As a guide on performing a statistical analysis, I used a book "Discovering statistics using SPSS" by Andy Field (2013). At the first step if analysis, I used the THI scores to divide participants into three respective groups; the control group, the group with lower level of tinnitus severity and the group with higher level of tinnitus severity. Afterwards, I ran one-way analysis of variances (ANOVAs) using the HADS scores and cognitive ability test scores as dependent variables and the classification by THI scores created in the first step of analysis as an independent variable. Tukey's B test, which is based on a studentized range distribution, was used as a post-hoc analysis for those variables where the one-way ANOVA that resulted significant *p* values. The usage of this specific test was motivated by the need to control the familywise Type 1 error rate, which, according to Field (2013) is a fundamental deficiency of statistical tests using repeated measures, such as one-way ANOVA. Instead of using other post-hoc tests suitable for controlling familywise error in multiple comparisons such as Bonferroni Procedure, Tukey's B was chosen since it has better resistance towards type II error when analyzing large numbers of means (Field, 2013). Using Fisher's Least Significant Difference (LSD) test, in turn, was advised against by Field (2013) because it does not control familywise error for multiple comparisons. Lastly, the Spearman correlation analysis between THI scores, HADS anxiety and depression scores and C scores from inhibition task results was ran in order to shed more light into their relationship. C scores were chosen from all inhibition test scores, since they provide information about differences among participants when it comes to an ability to inhibit conflicting responses. As mentioned in the previous section, the Spearman correlation analysis was chosen since the participant groups did not contain equal amounts of participants and because the analyzed variables were measured in ordinary scale. I used the alpha level of 0.05 with all the statistical tests involved in this study as a significance level.

4 Results

4.1 Descriptive Statistics

As mentioned in the section 3.2.1, we performed a median split (median = 20) of the tinnitus group based on the severity of the tinnitus symptoms. As a result, the tinnitus groups with lower and higher level of tinnitus severity (THI scores of 0-20 and 20-56) were formed. On Table 1, the descriptive statistics regarding to ages, THI scores, HADS Anxiety scores, HADS Depression scores, RST results and WAIS Block Design - and WAIS Word scores are presented for the control group and both tinnitus groups. The values are marked in a following format; mean(standard deviation). The used units of measurements are years for age, numbers of scores received from the questionnaires for THI score and HADS scores, total scores from WAIS Block Design test and numbers of correct answers for RST score and WAIS Word score.

Table 1. Results of descriptive statistics of ages (years), THI scores (total), two HADS scores (total), RST scores (number of correct answers), WAIS Block Design scores (total) and WAIS Word scores (number of correct answers).

	Age	**THI Score (total)**	**HADS Anxiety score**	**HADS Depression score**	**RST score**	**WAIS Block Design score**	**WAIS Word score**
Control n = 9	27.56 (10.04)	-	3.56 (1.94)	1.56 (1.130)	10.11 (3.56)	58.00 (6.75)	41.45 (4.21)
Tinnitus lower THI scores (THI 0-20) n = 12	41.25 (14.21)	13.17 (5.08)	3.92 (2.84)	1.92 (1.98)	9.58 (1.78)	49.75 (11.55)	43.75 (6.76)
Tinnitus higher THI scores (THI 20-56) n = 12	49.08 (10.67)	33.34 (11.89)	6.25 (4.11)	3.50 (3.18)	8.67 (2.15)	50.42 (9.85)	44.00 (6.76)

The results of audiometric test (PTA Left and PTA Right) were in line with previous studies since there were several cases of hearing impairment (WHO, 2017) among participants of tinnitus groups, yet none among the participants of the control group. The results of

descriptive statistics and of PTA Left and PTA Right can be found on Table 2. Similarly to Table 1, the results of descriptive statistics are written in the following format; mean(standard deviation). The used units of measurement were the mean audible threshold values of participants for frequencies 1000 and 4000 Hz. In the group with lower THI scores one participant had hearing impairment only on their right ear and two participants on both of their ears. In the other tinnitus group, there were three participants with only right ear hearing loss. In addition, one of the participants had a hearing deficiency in both of their ears. Apart from one of the participant in the group with less severe tinnitus symptoms who had a hearing loss classified as moderate (WHO, 2017) in both of their ears, the detected hearing impairments were mild. It was decided that the participants who suffered this level of hearing impairment would not be excluded from the study since, according to previous studies (for instance Andersson et al. 2009; Langguth et al. 2013; Salvi, 2016) mild to moderate hearing impairment has a high comorbidity with tinnitus symptoms and hence represents well the target group.

Table 2. Results of descriptive statistics of audiometric test results (mean audible threshold values of 1000 and 4000 Hz).

	PTA Left	**PTA Right**
Control n = 9	5.28 (4.04)	7.50 (4.68)
Tinnitus lower THI scores (THI 0-20) n = 12	14.17 (14.75)	15.21 (15.86)
Tinnitus higher THI scores (THI 20-56) n = 12	16.46 (8.49)	17.29 (9.80)

The results of the inhibition task (Stroop effect test) are presented on Table 3. The percentages of correct responses as well as the reaction times (in ms) are presented for the tasks A, B and C. Based on the scores “A”, “B” and “C”, the scores “D” and “E” were calculated in a way described in Jensen (1965), in other words using the formulas of D = A/(A + B) and E = C - A. The data used to calculate the results was reaction time (in ms) taken by participants to give the correct answer.

Table 3. Descriptive statistics of inhibition task results.

A (ms)	**A Correct responses (%)**	**B (ms)**	**B Correct responses (%)**	**C (ms)**	**C Correct responses (%)**	**D (ms)**	**E (ms)**

Control n = 9	783 (110)	69 (4.52)	792 (78)	71 (2.12)	881 (110)	66 (25.81)	.493 (0.21)	115 (67)
Tinnitus lower THI scores (THI 0-20) n = 12	785 (76)	70 (2.32)	776 (75)	72 (3.92)	874 (120)	57 (34.71)	.499 (.016)	108 (85)
Tinnitus higher THI scores (THI 20-56) n =12	874 (151)	66 (6.04)	889 (151)	67 (5.51)	1013 (133)	67 (21.76)	.496 (.026)	143 (123)

The score C resulting from five participants were excluded, since they either exceeded the maximum time given to answer or were unable to answer altogether. The excluded results contained three score C results from the group with lower THI scores (out of 12 results in total) and one result from both of the remaining groups, each initially containing 12 results. Also, the E results from the same participants were excluded since, as stated earlier, the score C was needed to calculate the score E. It was also studied whether the data contained any outliers that should be excluded. An outlier was defined as a result that exceeds the critical points known as outer fences. The outer fences were calculated by taking quartile 1 - 3*IQR (interquartile range) and quartile 3 + 3*IQR from the median value. However, no outliers were identified using this method. Hence, in total, five score C results and five score E results were excluded before calculating the results of descriptive statistics. The score C and E results (marked in grey in table 3.) were not included in the analysis of variance because the excluded data points would have posed a threat to validity of the test results (Field, 2013). However, the C scores were analyzed as a part of correlation analysis because the method is less sensitive for uneven number of variables as longs as each of the groups contains at least 8 data points (Field, 2013).

To summarize the results of descriptive statistic tests presented on Table 3, the tinnitus group with higher tinnitus scores have the longest reaction times with all parts of the test. The results of the tinnitus group with lower tinnitus scores are closer to the scores of the control group than to the scores of other tinnitus group. The D scores, that are almost identical in every group suggest that there may not be differences with the abilities to name colors after the reading speed is controlled, yet the analysis of variance is required to confirm this (Jensen, 1965).

4.2 One-way analysis of variance

First, a one-way analysis of variance was run to study if the participant groups differed from each other when it comes to the scores of the self-evaluation surveys (Hospital Anxiety

Depression Index (HADS) and the cognitive ability test results (Wechsler Adult Intelligence Scale (WAIS) tests, RST and Stroop task) (Table 4). Results that are significant at the alpha level of 0.05 are marked in bold. Same analysis was also used to investigate differences in inhibition task results (Table 5.) and audiometric test results (Table 6.) between different participant groups.

Table 4. Results of one-way ANOVA of ages (years), three HADS scores (total), RST scores (number of correct answers), WAIS Block Design scores (total) and WAIS Word scores (number of correct answers).

	Age	**HADS Anxiety score**	**HADS Depression score**	**RST score**	**WAIS Block Design score**	**WAIS Word score**
One-way ANOVA	***F* (2,30) = 8.40 *p* = .001**	*F* (2,30) = 2.36 *p* = .112	*F* (2,30) = 2.17 *p* = .132	*F* (2,30) = .928 *p* = .407	*F* (2,30) = 2.14 *p* = .136	*F* (2,30) = .511 *p* = .605

Table 5. Results of one-way ANOVA of inhibition task results.

	A (ms)	**A Correct responses (%)**	**B (ms)**	**B Correct responses (%)**	**D (ms)**
One-way ANOVA	*F* (2,30) = 2.25 *p* =.123	*F* (2,30) = 2.66 *p* = .086	***F* (2,30) = 3.62 *p* =.039**	***F* (2,30) = 3.51 *p* = .043**	*F* (2,30) = .207 *p* = .814

Table 6. Results of one-way ANOVA of audiometric test results (mean audible threshold values of 1000 and 4000 Hz).

	PTA Left	**PTA Right**
One-way ANOVA	*F* (2,30) = 3.13 *p* = .059	*F* (2,30) = 1.98 *p* = .156

As a result, there was a significant difference between groups only when it comes to ages ($F_{(2,30)} = 8.40$, $p = .001$) and B scores of inhibition task of participants, both for reaction times ($F_{(2,30)} = 3.62$, $p = .039$) and for percentages of correct responses ($F_{(2,30)} = 3.51$, $p = .043$). Post-hoc test (Tukey's B) showed that the participants were younger in the control group (M

= 27.56, SD = 10.04) than both the tinnitus groups (M = 41.25, p = .04; M = 49.08, p < .001), respectively for the lower THI group and for the higher THI group). There was no difference between the tinnitus group with lower (M = 41.25, SD = 14.21), and higher THI scores (M = 49.08, SD = 10.67) ($p \leq .05$). With B scores of inhibition task, the post-hoc test did not indicate any differences in reaction times between the control group (M = 792, SD = 78) and the group with lower THI scores (M = 776, SD = 75) (p = .94) or between the control group and the group with higher THI scores (M = 889, SD = 151) (p = 0.12). Nonetheless, the post-hoc comparison between the two tinnitus groups did led to a significant difference (p = .04). No differences were detected with the post-hoc comparison of the control group's percentages of correct B score responses (M = 71, SD = 2.12) and the responses of the two remaining groups. The test, however, showed significant differences between the groups with lower (M = 72, SD = 3.92) and higher THI Scores (M 67, SD = 5.51) (p = 0.04).

4.3 Correlation Analysis

Spearman's correlation analysis was run between the two HADS scores, THI scores, RST scores and C scores (reaction times (in milliseconds) and percentages of correct responses) from inhibition test results. The results are collected in Table 7. Correlations that are significant are marked in bold. As a result, a significant correlation (rs = .41, p = .019) was found between C score and THI Score. HADS Anxiety scores and THI scores showed correlation in a significance level of .05 (rs = .42), and the two HADS scores showed correlation (rs = .59, p < .001) that was significant at the alpha level of .01. The correlation between HADS Depression score and THI score was almost significant in the alpha level of .05 (p =.051).

Table 7. Spearman's correlation analysis of HADS anxiety and depression scores, THI scores, RST Scores and C scores from the inhibition test results.

		1	**2**	**3**	**4**	**5**	**6**
1	**THI Score**						
2	**HADS Anxiety Score**	***rs* = .42, *p* = .015**					
3	**HADS Depression Score**	*rs* = .34, *p* = .051	***rs* = .59, *p* < .001**				
4	**C (ms)**	***rs* = .41, *p* = .019**	*rs* = .12, *p* = .459	*rs* = .24, *p* = .189			
5	**C %**	*rs* = -.13, *p* = .477	*rs* = -.14, *p* = .432	*rs* = -.23, *p* = .203	*rs* = .15, *p* = .380		

6	**RST Score**	*rs* = -.24, *p* = .175	*rs* = -.09, *p* = .605	*rs* = .09, *p* = .620	*rs* = -.10, *p* = .595	*rs* = .13, *p* = .465

5 Discussion

5.1 Result discussion

Based on the former promising results, this study focused on unravelling how depression, stress and anxiety connected with tinnitus symptoms are related to cognitive abilities such as verbal fluency, inhibition ability and working memory capacity. Specific interest was taken to investigate whether there were differences in cognitive abilities or depression or anxiety symptoms between groups with lower and higher level of perceived severity of tinnitus symptoms. After reviewing the theoretical background of this study, the following two research questions were formed: “How the severity of tinnitus symptoms is related to cognitive abilities such as verbal fluency, inhibition ability and working memory capacity?” and “Are there differences in cognitive abilities or depression and anxiety symptoms between groups with lower versus higher level of perceived severity of tinnitus symptoms?”.

As the first stage of analysis, median split (median = 20) of the tinnitus group was done, resulting the groups with lower and higher level of tinnitus severity (THI scores of 0-20 and 20-56). Also, the control group of 9 participants was included in the study design since we were interested to study differences between tinnitus patients and healthy participants. The results suggest that the stress related to tinnitus symptoms as measured with THI is affecting on the performance in inhibition task B (where participants were asked to give the font color of congruent color - word pair as an answer) yet not on other cognitive abilities or anxiety and depression symptoms. The difference was found between the groups with lower and higher level of tinnitus severity, yet not between tinnitus groups and the control group. The resulted *p* values of variance analysis from age results and two variants of B scores (the reaction times) suggested significant variations among THI group means. Moreover, the post-hoc analysis (Tukey's B) indicated significant differences between the tinnitus groups when it comes to B scores. The analysis of variance and the post-hoc analysis also suggested that the participants in the control group were significantly younger compared to the experimental groups. As a result of correlation analysis, significant correlations were found between THI scores and HADS Anxiety scores as well as between THI scores and the reaction times taken to name the font color from incongruent color-word pairs (C (ms) scores of inhibition task).

- How the severity of tinnitus symptoms is related to cognitive abilities such as verbal fluency, inhibition ability and working memory capacity?

In some of the previous studies, it has been postulated that the effect of tinnitus on cognitive processing is greater with relatively undemanding and demanding processing as opposed to

moderately demanding tasks (Andersson & McKenna, 2006). However, the current study found evidence of this effect in the function of the used method to measure the perceived tinnitus severity (THI) only when it comes to the B scores of inhibition task. One interpretation of the results which cannot be overlooked is that apart from the task B, all of the cognitive ability tests used in this study can be, against our intentions, moderately demanding. Another explanation that should be addressed here is the different method that was used to measure the distress caused by tinnitus symptoms (Tinnitus Reaction Questionnaire (TRQ)), in the study by Andersson & McKenna (2006). It is possible that the THI scale cannot be associated with cognitive processing in a similar manner. This can be due to the fact that, in contrast with TRQ, THI focuses on both cognitive and emotional aspects of perceived tinnitus symptoms. Hence, the results of the current study question the coupling between perceived severity of tinnitus symptoms and cognitive abilities.

- Are there differences in cognitive abilities or depression and anxiety symptoms between groups with lower versus higher level of perceived severity of tinnitus symptoms?

Based on results by for example Moran (2016), Cho et al. (2013), Andersson et al. (2000) and Hallam et al. (2004), the working memory capacity and inhibition ability were expected to be correlated with both perceived severity of tinnitus symptoms and depression and anxiety symptoms. A comorbidity between anxiety symptoms and tinnitus symptoms among tinnitus patients was found (Cho et al. 2013). As a result of the correlation analysis, this study confirmed the pre-established connection between tinnitus symptoms and anxiety and depression symptoms. Based on the results of this study, it can be concluded that the anxiety scores and the scores of tinnitus severity questionnaire tend to increase and decrease together, which sheds more light into their relationship. Moreover, it was found that the response times of inhibition task regarding to the ability to name the font color from incongruent color-word pairs correlated with the stress related to tinnitus symptoms. In the former study by Andersson et al. (2000), similar results were gained using physiological assessment as a method to measure tinnitus. Hence, the current study where we focused on the perceived severity of tinnitus symptoms complements the prior knowledge about the connection between tinnitus symptoms and inhibition ability. When it comes to working memory capacity or depression symptoms, they did not correlate significantly with any of the other variables. As discussed in the section 2.5., some of the possible explanation for these non-significant results are small number of participants of this experiment as well as the possibility that the used methods to study working memory capacity and depression, Reading Span Test (RST) and HADS depression score, may not be optimal methods when studying tinnitus patients despite of the former promising results.

Aside from the results regarding to result question, there was an interesting finding that came up when structuring the data. Three score C reaction time results were excluded from the group with lower THI scores and the results of only one participant were excluded from both of the groups with tinnitus patients. This could be for instance due to some form of connection between the inability to carry out the inhibition test as a whole and low (2-20) tinnitus scores.

This connection could, for instance be better adaptation (inhibition) of the symptoms for tinnitus patients with higher scores. However, further testing is required to confirm the existence of this connection.

5.2 Method discussion

In the following sections, a discussion about the used methods and the reliability and validity of the results will take place. Also, some ideas for the future research based on the results of this study will be presented. The discussion will begin by addressing some of the possible sources of error regarding to the scale of Tinnitus Handicap Inventory. The most serious possible threat of validity related to THI scale takes place due to the fact that no differences were found between groups classified by THI scores in performance in cognitive ability tests results (other than B scores of inhibition task) or in the level of anxiety and depression symptoms, despite of the former promising results gained with other types of classification methods related to tinnitus symptoms. In the worst-case scenario, this can result from an issue with either a poor reliability of the method, or from an unsuccessful operationalizing of the perceived level of tinnitus severity, which would lead, among other things, to a diminished construct validity of the experiment. However, since the method has been proven to be reliable and valid according to some of the previous studies (Frank et al. 2015), these interpretations are not likely to be accurate.

For the practical reasons, the classification of results into different tinnitus groups was not done according to the official THI questionnaire. The choice to divide the experiment group into two sub-groups separated by median value was done for the sake of getting enough participants into each group. Had the classification been done according to the categories of THI questionnaire, the group with tinnitus score “moderate” (score from 38 to 56) would have consisted only 5 participants, which would have likely diminished the validity of the results. However, since this kind of classification was done solely for the purpose of this study, it makes the results less generalizable and hence effects on the external validity of the results.

Next, the discussion will shift into some of the possible sources of error related to the participant groups. One of the most evident defects of this study is the small sample size that was chosen because of the nature of the study (bachelor thesis). None of the participant groups contained over 12 participants. Despite of the participant numbers being within the normal guidelines followed by the field, it should not be overlooked that the small number of participants can lead to low statistical power of the study and to underpowered statistical testing (Field, 2013).

In the analysis of variance, it was found that the participants in the control group were significantly younger than the participants in the two experimental groups. Even though hardly any significant differences were found between the control group and the groups with lower and higher level of tinnitus severity, this result could have poses a threat to an external validity of the study results. Because of the effect aging has on the cognitive abilities, it is possible that the age difference would have acted as a confounding variable, should the

greater part of the results have been significant. In the future studies it would hence be preferable to have a control group and a participant group matched by age.

The possibility that the experiment group may not be a representable sample of the target group, the Swedish speaking adults with tinnitus symptoms, is also one of the possible threats of the external validity of this study. This possibility should be discussed albeit we used an online advertisement as a method of recruitment to reach a bigger part of target audience than it would have been possible with more conventional methods, such as via posting an advertisement to a noticeboard of a health care center. By reaching the bigger part of target audience, we sought to avoid selection bias in recruitment process. However, it may be the case that the participants who ended up answering to the advertisement were more knowledgeable about the effects of the tinnitus and were hence able to cope better with the symptoms. This phenomenon could explain that none of the participants got more than a score "moderate" (3) in a range from 1 to 5 or from "slight" to "catastrophic" in Tinnitus Handicap Inventory. Further studies are therefore required to see whether high THI scores have significant interaction effect with the dependent variables.

Another potential cause for the lack of representability is also that the uptake of antianxiety and antidepressant medicines was part of excluding criteria. As mentioned in the introduction, tinnitus has a high comorbidity with both anxiety and depression. Hence it is likely that a significant part of tinnitus patients has tried psychiatric medication. It may be the case that the selected participants were able to cope better with their anxiety and depression symptoms, which in turn results the absence of significant interaction effect. In future studies, it would be interesting to compare the cognitive ability test results between tinnitus patients with and without antidepressant or antianxiety medication.

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Appendix

Appendix A

List of questions in Tinnitus Handicap Inventory

1. Because of your tinnitus, is it difficult for you to concentrate?
2. Does the loudness of your tinnitus make it difficult for you to hear people?
3. Does your tinnitus make you angry?
4. Does your tinnitus make you feel confused?
5. Because of your tinnitus, do you feel desperate?
6. Do you complain a great deal about your tinnitus?
7. Because of your tinnitus, do you have trouble falling to sleep at night?
8. Do you feel as though you cannot escape your tinnitus?
9. Does your tinnitus interfere with your ability to enjoy your social activities (such as going out to dinner, to the movies)?
10. Because of your tinnitus, do you feel frustrated?
11. Because of your tinnitus, do you feel that you have a terrible disease?
12. Does your tinnitus make it difficult for you to enjoy life?
13. Does your tinnitus interfere with your job or household responsibilities?
14. Because of your tinnitus, do you find that you are often irritable?
15. Because of your tinnitus, is it difficult for you to read?
16. Does your tinnitus make you upset?
17. Do you feel that your tinnitus problem has placed stress on your relationships with members of your family and friends?
18. Do you find it difficult to focus your attention away from your tinnitus and on other things?
19. Do you feel that you have no control over your tinnitus?
20. Because of your tinnitus, do you often feel tired?
21. Because of your tinnitus, do you feel depressed?
22. Does your tinnitus make you feel anxious?
23. Do you feel that you can no longer cope with your tinnitus?
24. Does your tinnitus get worse when you are under stress?
25. Does your tinnitus make you feel insecure?

Answer options and their corresponsive scores

- Yes (4 points)
- Sometimes (2 points)
- No (0 points)

Grading of Tinnitus Handicap Inventory scores

Table 8. Grading instructions of THI

Score	Grade	Description
0 - 16	1	Slight
18 - 36	2	Mild
38 - 56	3	Moderate
58 - 76	4	Severe
78 - 100	5	Catastrophic