The impact of tinnitus on cognitive performance in normal-hearing individuals.

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The Impact of Tinnitus on Cognitive Performance in Normal Hearing Individuals

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Key words:

Tinnitus, Cognitive performance, Normal Hearing, Stroop

Abbreviations and acronyms:

dB HL – decibel Hearing Level

HADS – Hospital Anxiety and Depression Scale

Hz – Hertz

PTA – Pure Tone Audiometry

SD – Standard deviation

TQ – Tinnitus Questionnaire

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Abstract

Objective

The aim of this study was to investigate whether the previously reported differences in cognitive performance as assessed using a Stroop paradigm between individuals with and without tinnitus is present in normal hearing individuals.

Design

Participants completed audiometric evaluation, a visual Stroop test, as well as the Swedish version of the Hospital Anxiety and Depression Scale (HADS). In addition individuals with tinnitus participated in a short interview regarding tinnitus characteristics as well as a follow up data collection of the Tinnitus Questionnaire (TQ).

Study sample

40 individuals participated in this study. 20 had tinnitus (tinnitus group) and 20 had not (control group). The groups were age- and sex matched and all participants had normal hearing thresholds (20 dB HL or better).

Results

No differences in terms of cognitive performances were found between individuals with tinnitus compared to individuals without tinnitus.

Conclusion

In contrast to previous studies of hearing impaired subjects with tinnitus, the results of the present found no signs of cognitive interference in normal hearing subjects with tinnitus when assessed using intensive short duration tasks.

Introduction

Tinnitus is known as the individual's perception of a sound in the absence of external acoustic stimulus, and has been linked with cognitive interference as tinnitus patients have recurrently reported concentration difficulties (Andersson et al., 1999; Hallam et al., 1988; Hallam et al., 2004; Tyler & Baker, 1983). Several underlying causes for tinnitus have been suggested, such as the discordant damage of inner and outer hair cells, calcium, sponaneous otoacoustic emissions etc. (see Jastreboff, 1990 for an overview of tinnitus generation), however is it yet not clear how tinnitus impairs cognition and whether the effect is linked to certain types of tinnitus or not. As subjective experiences do not serve as evidence for a link between tinnitus and reduced cognitive performance, several studies have investigated whether the self-reported cognitive deterioration in tinnitus patients is solely subjective or if it is objectively measurable. This has typically been done by comparing the performance of individuals with and without tinnitus on selective attention task conditions that have high demands on the participants' attentional control.

The general finding in previous studies has been that individuals with tinnitus have longer response times on cognitive tests compared to individuals without tinnitus (Andersson et al., 2000; Dornhoffer et al., 2006; Hallam et al., 2004; Jackson et al., 2014; Rossiter et al., 2006; Stevens et al., 2007). One common strategy in these studies has been to use different variations of Stroop tests to evaluate the cognitive performance. Stroop tests typically use a stimulus that can be interpreted in two ways, but the participants' task is only related to one of them. The task-irrelevant interpretation can either be interfering or not. When the stimulus contains information that could be interfering with the task-relevant information, the participant is forced to suppress the task-irrelevant information of the stimulus in order to accomplish the task. This increases the task difficulty and gives a measure of the participants'

ability to direct attention. The effect was first shown by Stroop (1935) and modified versions of the original test have been widely used in the field of psychology ever since.

Anxiety and depression seem to be common amongst a portion of the tinnitus population (Rizzardio et al., 1998), which might influence their cognitive performance (Cisler & Koster, 2010; Kaiser et al., 2003; Peckham et al., 2010). Due to this, previous studies were controlled for the possible influence of psychological factors. This has been done using inter alia the HADS, which is used to screen for anxiety and depression amongst patients (Zigmond & Snaith, 1983). Most previous studies have reported higher levels of anxiety and depression in their tinnitus groups compared to controls (Andersson et al., 2000; Hallam et al., 2004; Rossiter et al., 2006; Stevens et al., 2007). While Jackson et al. (2014) reported a correlation between anxiety and task performance, the majority of previous studies investigating this possible link do not indicate that neither anxiety nor depression would correlate with task performance (Andersson et al., 2000; Rossiter et al., 2006; Stevens et al., 2007). In order to facilitate comparison to previous studies the present study used the HADS to control for anxiety and depression.

Tinnitus distress has been suggested as a factor that could play a critical role in the degree to which tinnitus has a negative impact on cognitive performance (e.g. Jackson et al., 2014; Rossiter et al., 2006; Stevens et al., 2007). The general assumption is that "tinnitus may cause the anxiety and emotional distress that, in turn, disrupts cognitive processes" (Stevens et al., 2007) and that greater tinnitus distress entails "greater allocation of finite resources to the tinnitus sensation" (Jackson et al., 2014). There have been various ways of measuring tinnitus distress, one of them being the Tinnitus Questionnaire (TQ) developed by Hallam et al. (1988). Previous studies have investigated cognitive performance in individuals with low,

medium and severe levels of tinnitus distress (Andersson et al., 2000; Dornhoffer et al., 2006; Jackson et al., 2014; Rossiter et al., 2006; Stevens et al., 2007). Jackson et al. (2014) as well as Stevens et al. (2007) reported significant positive correlations between tinnitus distress score and response time (i.e the more distress the longer response times), while Dornhoffer et al. (2006) reported a lack of significant correlation between distress and response times. The remaining studies that included a measure of tinnitus distress did not report that they had performed a correlation calculation comparing degree of tinnitus distress and task performance (Andersson et al., 2000; Rossiter et al., 2006). As tinnitus distress could play a central role in task performance, the present study used TQ to exclude the absence of tinnitus distress as a possible confounder.

Previous studies that examined cognitive performance in persons with and without tinnitus did however have some limitations. In the study conducted by Andersson et al. (2000), individuals with hearing loss were included in the tinnitus group, whereas hearing status of the control group was not reported. In the study conducted by Dornhoffer et al. (2006) participants were only excluded from the tinnitus group due to their hearing if hearing thresholds were worse than 90 dB at 4000 Hz. Hallam et al. (2004) compared cognitive performances in a group of tinnitus patients to those of a group of hearing-impaired and a non-clinical group, but participants were only excluded from the tinnitus group due to their hearing if it disabled conversations in quiet environments. Moreover Rossiter et al. (2006) did not report the participants' hearing thresholds while Stevens et al. (2007) included individuals with hearing loss in the tinnitus group as well as the control group (yet of somewhat milder degrees for the control group). Jackson et al. (2014) examined participants who were not hearing aid users or had previously been advised to use hearing aids; this was their sole inclusion criterion regarding hearing status. Taking into consideration that previous studies

have indicated that hearing loss can have negative effects on cognitive performance (e.g. Lin et al., 2011), one cannot rule out the possibility that hearing loss amongst the participants with tinnitus might have influenced the results of previous studies investigating the impact tinnitus had on cognitive performance (Andersson et al., 2000; Dornhoffer et al., 2006; Hallam et al., 2004; Jackson et al., 2014; Rossiter et al., 2006; Stevens et al., 2007).

Therefore, this study aims to investigate whether tinnitus has an impact on cognitive performance in individuals with confirmed normal hearing thresholds. This is done by assessing the performances of normal hearing individuals with and without tinnitus on a modified visual Stroop test. We hypothesize the response times to be longer in the tinnitus group compared to the control group and no differences in terms of accuracy to be found between the groups.

Method

Participants

A total of 40 adult volunteers participated in the study (see demographic data in table 1). Of these 20 had experienced tinnitus for the past 6 months or longer (see tinnitus characteristics in table 2) and 20 who were age- and sex-matched with the individuals with tinnitus. The volunteers were recruited from audiological clinics in southern Sweden, through personal contacts and public advertising. Inclusion criterion for participation was hearing thresholds of 20 dB HL or better at octave intervals 125 to 8000 Hz, measured with equipment calibrated in accordance with ISO 389-1 (1998). No statistically significant differences in terms of hearing thresholds were found between the groups. Inclusion criteria for participants in the control group were to be of the same sex as a participant in the tinnitus group and to differ no more than 12 months of age compared to that individual at the time of

testing. No statistically significant differences in terms of age were found between the groups. There was no inclusion criterion regarding socioeconomic status, but almost all individuals included in this study had participated in higher education. Prior to conducting the study, ethical clearance was obtained from the Regional Ethical Review Board in Lund (approval number 2014/95). All participants agreed in writing to the conditions of the study. Initially 46 participants were recruited for the study. After exclusion of 6 individuals (of which 5 belonged to the tinnitus group) due to impaired hearing thresholds, the 40 participants described above remained.

Procedure

First, the participants' hearing thresholds were assessed in accordance with international standard for audiometric test methods (ISO 8253-1, 2010). The assessments were carried out using a Madsen Astera^2 (GN Otometric) audiometer and TDH-39 earphones (Telephonics), calibrated in accordance with ISO 389-1 (1998).

Thereafter the participant was seated in front of a computer screen to perform a modified visual Stroop test. Groups of symbols ("1", "2", "3", "4" or "#"), presented one group at a time on the screen were used as stimuli. Each group consisted of 1-4 symbols of one of the above-mentioned types. The participant's task was to indicate on a wireless keyboard (1) the number of symbols within the group when the group was presented on white background and (2) the symbol type when the group was presented on yellow background (hereinafter referred to as stimulus type "switched task"). Participants were instructed in writing as well as verbally to answer correctly and as fast as possible at each trial. A new group of symbols was presented immediately after a response was given. If the participant failed to respond within 4000 ms, the next group of symbols was presented. One hundred

thirty-two stimuli, of which 100 on white background and 32 on yellow were presented at random order. The purpose of the yellow background condition was to force the participants to switch task, which supposedly would increase test difficulty. Out of the 100 stimuli presented on white background 20 were congruent (i.e. the value of the symbol presented and the number of symbols within the group being the same, e.g. "333"), 60 were incongruent (i.e. the value of the symbol presented and the number of symbols within the group being different, e.g. "44") and 20 were neutral (i.e. the symbol presented having no value, e.g. "#"). The Stroop test was written in E-Studio 2.0 (E-Prime Professional), and presented via E-Run 2.0 (E-Prime Professional).

Finally, every participant filled out a Swedish version of the Hospital Anxiety and Depression Scale (HADS) questionnaire (Zigmond & Snaith, 1983), see scores in table 1. The scale consists of 14 items, half of them measuring the respondent's anxiety and half of them measuring the respondent's depression. Scores range from 0-21 for each sub-scale, where scores < 8 are categorized as normal, scores of 8-10 as borderline and 11-21 as clinical levels of anxiety or depression depending on subscale (Zigmond & Snaith, 1983). The original version of HADS has shown good validity for the general population (see Bjelland et al., 2002, for review of validation studies of HADS), and the Swedish version of it seems to be "useful as a brief clinical indicator of possible depression and clinical anxiety" (Lisspers et al., 1997, p. 285) as well. An additional short interview was conducted with the participants of the tinnitus group to identify tinnitus lateralization, character and severity according to the Klockhoff tinnitus severity scale (Klockhoff & Lindblom, 1967) (see table 2). Approximately 6 months after the time of testing participants of the tinnitus group were asked to complete the TQ (Hallam et al., 1988) for a follow up data collection. The TQ is a 52-item questionnaire providing a measure of the most commonly reported complaints and dimensions of tinnitus

distress, and has shown good test-retest reliability (Hiller et al., 1994) as well as high validity (Snow, 2004).

Results

Visual inspection of the histograms as well as Q-Q plots, calculation of skewness and kurtosis z-values of collected data indicated normal distribution of HADS scores. T-tests revealed no significant differences between the groups in terms of total- ($t = 1.143$, $p = 0.945$), anxiety- ($t = 1.200$, $p = 0.832$) or depression scores ($t = 0.409$, $p = 0.983$) on HADS (see table 1 for ranges, average and standard deviations).

The follow up data collection of the TQ revealed mean scores of 40.05, SD = 13.53 (range 16-61) for 19 of the tinnitus participants, as one participant could not be reached. Mean subscale scores: emotional distress: 17.1 (SD = 7.4), auditory perceptual difficulties: 7.2 (SD = 3.2), intrusiveness: 7.8 (SD = 3.4), sleep disturbances: 4.1 (SD = 2.1), somatic complaints: 3.9 (SD = 1.4). 16 out of 19 tinnitus participants reported that the statement "the noises have affected my concentration" was true or partly true, remaining 3 participants reported that their tinnitus noises had not affected their concentration.

Visual inspection of the histograms as well as Q-Q plots, calculation of skewness and kurtosis z-values of collected data indicated significant deviations from normal distribution for accuracy on the Stroop test, but indicated normal distribution for response times on the Stroop test. All statistical analyses were performed at the 5% level using IBM SPSS Statistics Version 22.0.0.0 64 bit edition for Macintosh (IBM SPSS, 2013).

Stroop accuracy

Figure 1 shows the group performance in terms of accuracy (percent correct) on the Stroop test (see table 3 for ranges, average and standard deviations). Friedman test was used to assess within-subject effects in each group. Significant effects were further explored using post-hoc Wilcoxon signed Ranks tests with Bonferroni correction. Mann-Whitney U test was used to determine whether accuracy differed between the groups. The overall tendency for the participants' accuracy on the Stroop test was that the accuracy was highest when presented with congruent stimuli, that the performances declined when presented with neutral stimuli, declined further when presented with incongruent stimuli and that the accuracy was lowest when presented with switched task stimuli. Friedman test revealed significant differences amongst the accuracy for different stimulus types ($\chi^2(3, N = 20) = 53.783$, $p < 0.001$). Post-hoc analysis revealed significant differences amongst all stimulus types, except for congruent vs. neutral and incongruent vs. switched task for both groups ($p < 0.05$). Overall, the performances of the tinnitus group and the control group were quite similar and Mann-Whitney U test revealed no significant differences between the groups' performances for any stimuli or auditory condition (see table 3 for z- and p-values).

Stroop response times

An ANOVA with repeated measures assessed within subject effects to determine whether response times differed between the groups. The ANOVA included one within-subject variable (Stroop response time in ms for only correct responses), one between-subject variable (tinnitus group compared to control group), and interaction effects. Significant effects were explored using post-hoc t-tests with Bonferroni correction. Figure 2 shows the total group performance in terms of response times on the Stroop test (see table 4 for ranges, average and standard deviations). Response times were shortest for neutral stimuli, the response times were to some extent prolonged when presented with congruent stimuli, further

prolonged when presented with incongruent stimuli and the longest response times were recorded when presented with switched task stimuli. The within-subject effects were significant as shown in table 4. The ANOVA with repeated measures revealed no significant between-group effects for response times ($F(1, N = 40 = 0.651$, $p = 0.587$). No interaction effects were seen.

Discussion

The aim of the present study was to investigate whether tinnitus influences cognitive performance in individuals with confirmed normal hearing. In summary, the findings indicate that the tinnitus group and the control group perform equally in terms of accuracy as well as response times for all stimulus types. This finding differs from previous studies that reported individuals with tinnitus have longer response times on cognitive tests when compared to individuals without tinnitus (Andersson et al., 2000; Dornhoffer et al., 2006; Hallam et al., 2004; Jackson et al., 2014; Rossiter et al., 2006; Stevens et al., 2007). The fact that this study has only included individuals with confirmed normal hearing thresholds distinguishes it from previous studies in terms of study design. Because hearing impairments have been linked with declined cognitive performances (e.g. Lin et al., 2011), this suggests that previous findings may have been biased by hearing status and that cognitive deterioration in tinnitus sufferers might not be present in absence of hearing impairment. The tinnitus group and the control group did not differ in terms of anxiety, depression or level of education, and it is therefore assumed that neither psychological nor socioeconomic status was critical for the results.

When the expected difference in terms of response time between the groups was not found, the question arises whether it was not found because the difference was not present or if the sample size used may have made it difficult to detect the differences that might have

existed between the groups. In order to carry out accurate calculations of our statistical power we had to estimate the size of the effect searched for. The size of the effect reported by previous studies has been quite large - up to 1,80 (for one of the Stroop tasks reported by Andersson et al., 2000) and never lower than 0,47 (for the incongruent Stroop task reported by Jackson et al., 2014). To determine how great the risk was that we had missed the differences in response time due sample size, we conducted post hoc calculations of achieved statistical power using the G*Power 3.1 (Faul et al., 2009). When using the lowest effect size found in previous studies (0,47), our ANOVA has a statistical power of 0,956 when using 40 participants divided into two equal groups. In other words, the risk that we have missed a difference in response time between the groups due to our sample size is very small – less than 5 %. We therefore draw the conclusion that our sample size was sufficient.

The fact that there were no significant differences between the tinnitus group and the control group implies that the participants of this study differed from the population of some of the previous studies, in which the tinnitus group was more depressed (Andersson et al., 2000; Stevens et al., 2007) and had greater anxiety compared to their controls (Andersson et al., 2000; Hallam et al., 2004; Rossiter et al., 2006; Stevens et al., 2007). However, the anxiety- and depression scores of the present study are similar to those reported by Jackson et al. (2014). Jackson et al. (2014) found no significant differences in terms of anxiety or depression between the groups yet the group performances were similar to previous studies (i.e. significant longer response times in tinnitus subjects). This suggests that the absence of differences in response time between tinnitus and control group most likely cannot be attributed to our participants' degree of anxiety or depression.

The follow up data collection of TQ revealed a mean score of 40.05 (range 16-61) for tinnitus participants of the present study. It is essential to emphasize that the TQ scores were not collected at the same time as the rest of the data, which is a source of error we cannot disregard. Due to this uncertainty we have chosen not to investigate possible links between individual TQ score and Stroop performance, but we do believe our follow up data collection gives a reasonable indication of the degree of tinnitus distress on a group level. The scores indicate that we had individuals represented in all four quartiles and the tinnitus group's mean score was just below the 50 % quartile cut off as well as very similar to the total TQ mean reported by Hallam (2008). The degree of tinnitus distress varies a lot among previous studies in the area of interest, some have only included moderate to severe tinnitus (Andersson et al., 2000; Rossiter et al., 2006) as this supposedly "maximized the chances of obtaining significant results from a sample of manageable size" (Rossiter et al., 2006). Others have explored a wider range of tinnitus distress (Stevens et al., 2007), or only investigated individuals with mild to moderate tinnitus, to determine whether longer response times were present in these individuals as well (Jackson et al., 2014). And in some cases tinnitus distress was not reported (Dornhoffer et al., 2006; Hallam et al., 2004). All studies have nevertheless reported significant longer response times for the tinnitus group. Comparing the tinnitus distress of the present study with previous studies is not easily done, partly because of the aforementioned time lag between the time of testing and the collection of TQ scores and partly because the method of measuring tinnitus distress varies among previous studies. The mean TQ scores of the present study are somewhat lower than reported by Stevens et al. (2007), but the ranges overlap entirely. This, combined with the fact that Jackson et al. (2014) only observed individuals with mild to moderate tinnitus and still reported poorer cognitive performances for the tinnitus group, leads the authors of this article to draw the conclusion

that the inconsistency of our results compared to previous studies' most likely cannot be explained by low degree of tinnitus distress.

The results of the present study leave us with three main hypotheses for the future. Either

a) Tinnitus itself does not impair cognitive performances, and the earlier reported tinnitus impact on cognition might be a result of the hearing status of the participants

or

b) Tinnitus in combination with an hearing impairment constitutes a greater cognitive load than either of the conditions isolated, resulting in differences in cognitive performances between individuals with a combination of tinnitus and hearing impairment compared to individuals without that combination.

or

c) Tinnitus might interfere with cognitive performances in normal hearing individuals, but the abilities that are affected do not affect the results of the Stroop test.

A possible explanation as to why a combination of tinnitus and hearing impairment could cause greater cognitive load is that the negative effects of a simultaneous irrelevant auditory stimulus might be increased as the input signal of relevant stimulus is degraded. Previous studies have reported weaker cognitive performances in individuals with a combination of tinnitus and hearing impairment, compared to the performances of individuals with hearing impairment but no tinnitus (e.g. Hallam et al., 2004; Stevens et al., 2007), suggests the possibility of hypothesis b). However, none of the studies showing such results matched the hearing impairments of the groups. The cause for the absence of attempts to match hearing impairments might be that hearing seems to be quite individual and, as many

clinicians have witnessed – an audiogram is far from a complete measure. Nevertheless, the authors considered the audiogram an adequate and feasible measure of hearing sensitivity for the current study.

However, hypothesis c) - that the cognitive performance is not affected in normal-hearing individuals with tinnitus as measured by the Stroop test - is also feasible, as this study has assessed the participants' cognitive performances using only a Stroop test. The test was chosen in order to enhance comparability to previous literature. But since cognitive abilities that do not affect the Stroop results were not measured, tinnitus might have influenced normal-hearing individuals' cognitive performance, although in an unexpected manner. After all, the complaint of concentration problems is still common in tinnitus sufferers. Additionally, as 16 out of 19 tinnitus participants of this study reported that their tinnitus had affected their concentration in general it does seem likely that tinnitus might entail cognitive interference which could not be measured with the present study design.

Limitations

There could be other possible causes (than hearing status) to why the finding of this study is inconsistent with previous studies. Using a different version of the Stroop test (not utilizing the word/colour paradigm) could be one reason. Furthermore, our data indicate a lack of significant difference within subjects between response times for congruent and incongruent stimuli ($p = 0.063$). This is inconsistent with the traditional Stroop effect (Stroop, 1935), which limits the conclusions that can be drawn from the present data. Although these are possible sources of error that should not be disregarded, there are reasons to believe that differences in response time between the groups should have been triggered for this version of the test as well: Andersson et al. (2000) demonstrated longer response times in tinnitus

patients compared to non-tinnitus controls on all six versions of the Stroop task they tested, i.e. not only when performing the traditional word/colour version but on a range of stimuli. This led us to conclude that the tinnitus sufferers seem to perform worse on Stroop tests in general, rather than a specific version of the test. Also, longer response times seem to be the consistent finding from previous studies, even when using other test paradigms (Dornhoffer et al. 2006; Rossiter et al. 2006).

Another possible reason could be the age of our participants, as this study differs from previous ones in that regard. The age range (20.9-55.2 years old for the present study) is quite similar to what previous studies have reported (18-64 years old (Steven et al., 2007), 30-63 years old (Rossiter et al., 2006), 20-68 years old (Andersson et al. 2000) and 30-80 years old (Dornhoffer et al., 2006)), but the mean age is clearly lower for the present study (29.6 years old) compared to previous studies (about 50 years old in all). On the other hand, the participants in the present study were more accurately age-matched compared to most previous studies (maximum 12 months of age difference between tinnitus- and control participants), and if tinnitus truly has been the reason for cognitive interference in previous studies it would probably affect younger tinnitus sufferers as well. However, at the time of writing we cannot rule out the possibility that tinnitus might influence older patients more severely than younger ones.

A further limitation of the present study is the usage of a wireless keyboard, as there is a possibility that the latency and time resolution of the wireless keyboard could have had an impact the recordings of response time. This might have led to somewhat greater standard deviations in individual cases; however, on group level it should not have an impact as it affects both groups likewise.

Future research

There is a possibility that tinnitus might impact cognitive abilities that do not affect the results of the Stroop test in normal hearing individuals, and therefore future research should explore the impact of tinnitus on other cognitive tasks. Practically all studies within this field have focused on short, intensive cognitive tasks, while our participants' every day life might require long and steady concentration rather than the ability to respond a couple of hundred ms faster on a task that does not last for more than a couple of minutes.

The possibility that certain tinnitus characteristics might interfere more with cognitive operations than others was not investigated in this study due to the low number of observations. However, because it has been reported that certain tinnitus characteristics are more prevalent amongst individuals who are searching professional help due to their tinnitus (Hallberg & Erlandsson, 1993) this possibility should be investigated in future studies.

Future research should also attempt to investigate whether cognitive performances within the same individual changes depending on presence and absence of tinnitus, perhaps by temporarily inducing or removing tinnitus. The general strategy while exploring the possible link between tinnitus and deteriorated cognitive performances has been to compare the performances of individuals with tinnitus compared to a somewhat matched control group. This can give us clues about the impact of tinnitus, but it cannot give evidence since we cannot know how the tinnitus group performed pre tinnitus or how they would perform if their tinnitus would be absent. To solely compare a groups performances to another group does not reveal whether their performances have declined due to a certain condition or not.

Furthermore, it would be of interest to explore the impact a pair of adequately fitted hearing aids could have on the participants' cognitive performances. If the poorer cognitive performances found in tinnitus patients in previous studies were due to hearing loss or the combination of hearing loss and tinnitus, then this intervention might improve the tinnitus patients' performances. However, cognitive deterioration that occurs as a result of hearing loss likely requires an extended period of reduced stimulation and would be expected to vary considerably across patients. Similarly, the reversibility of this process, or the rate at which a patient's cognitive performance would improve when relying upon adequately fitted hearing aids, would be difficult to predict.

In summary, the present findings indicate that cognitive interference in tinnitus sufferers might not be present in absence of hearing impairment, at least not in intensive short duration tasks. This is inconsistent to previous studies in which hearing impairment may have been a confounding factor.

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Table 1. Demographic data of participants. HADS-A and –D scores <8 is categorized as normal, scores of 8-10 as borderline and 11-20 as clinical anxiety and depression (Zigmond & Snaith, 1983).

		Total	**Tinnitus group**	**Control group**
N		40	20	20
Sex	*F*	22	11	11
	M	18	9	9
Age (years)	*Span*	20.9-55.2	21.8-55.0	20.9-55.2
	Average	29.6	30.3	30.3
	Median	26.3	26.3	26.3
	SD	8.9	9.0	9.1
PTA Average of 500, 1000, 2000 and 4000 Hz (worst ear)	*Span*	-4-16	-4-16	-3-15
	Average	4.8	3.6	6.1
	SD	5.2	5.5	4.7
HADS total score	Span	3-22	4-22	3-19
	Average	10.6	11.4	9.7
	SD	4.7	4.7	4.7
HADS Anxiety score	*Span*	1-17	2-17	1-14
	Average	7.3	8.0	6.6
	SD	3.7	3.8	3.6
HADS Depression Score	*Span*	0-12	1-12	0-9
	Average	3.3	3.4	3.1
	SD	2.3	2.5	2.1

Table 2. Tinnitus characteristics.

	Severity (Klockhoff gradation)			Lateralization		Character			Time with tinnitus (months)		Previous contact with health care
	1	2	3	Bilateral	Perceived as a sound inside the head	Tone and/or noise, non-fluctuating	Tone or noise, fluctuating	Tone and noise, fluctuating	Span	Average	
N	3	17	0	17	3	8	6	6	6-360	154	8

Table 3. Ranges, average, standard deviation for accuracy on the Stroop test, for each group, stimulus type along with z- and p-values from the Mann-Whitney U test.

	Tinnitus group			**Control group**			**Mann-Whitney U**	
	Range (%)	*Average (%)*	*SD*	*Range (%)*	*Average (%)*	*SD*	*z*	*p*
Congruent	88-100	97.9	3.6	67-100	98.4	7.4	-1.920	0.211
Neutral	80-100	97.9	4.8	75-100	96.5	6.8	-0.619	0.620
Incongruent	82-100	93.4	5.5	77-100	95.2	5.3	-1.306	0.201
Switched task	79-100	92.6	5.4	47-100	91.2	12.6	-0.750	0.461

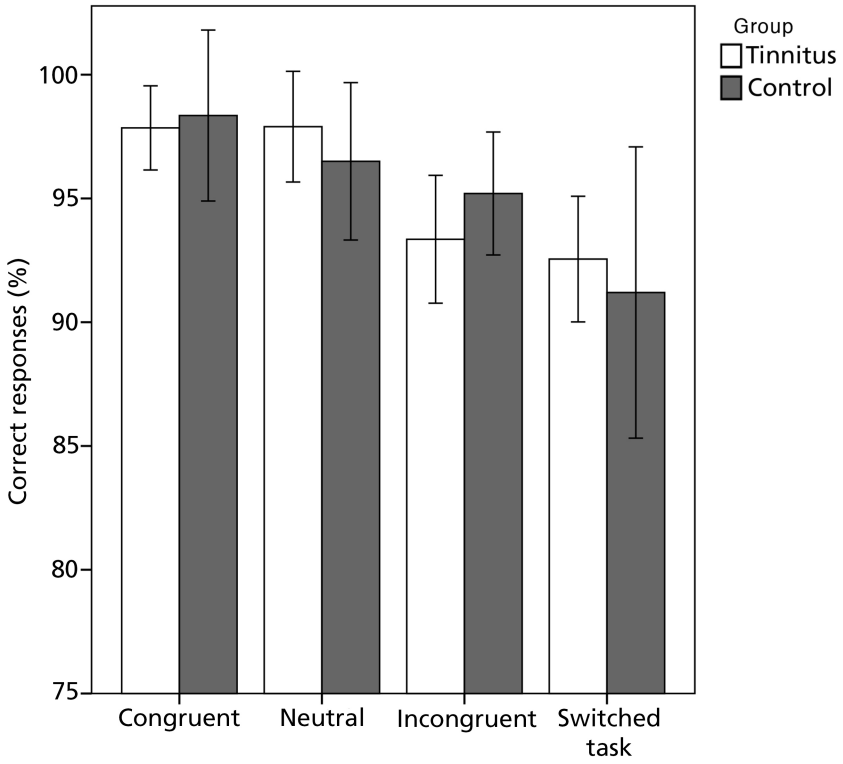
Table 4. Ranges, average, standard deviation for response times on the Stroop test, for each group and stimulus type. B for "between-subjects", W for "within-subjects", N.s. for "non-significant", * for p<0.05, ** for p<0.01, *** for p<0.001.

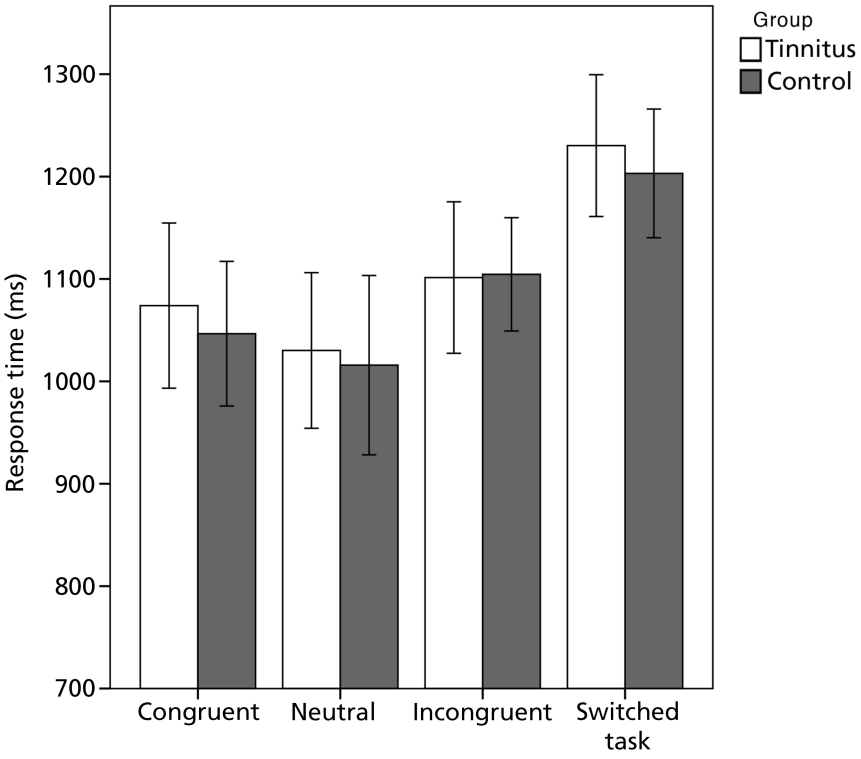
	Tinnitus group			**Control group**				**Condition 1-2-3-4**					
	Range (ms)	*Average (ms)*	*SD*	*Range (ms)*	*Average (ms)*	*SD*	F-value	1-2	1-3	1-4	2-3	2-4	3-4
Condition 1: Congruent	668-1456	1074	172	803-1306	1047	151	W: 48.890 B: N.s.	**	0.063	***	***	***	***
Condition 2: Neutral	754-1381	1030	162	758-1310	1016	187							
Condition 3: Incongruent	826-1460	1101	158	907-1317	1105	118							
Condition 4: Switched task	914-1601	1230	148	978-1467	1203	134							

Figure legends

Figure 1. Mean percentage correct responses for each group and stimulus type. Confidence interval for error bars: 95 %.

Figure 2. Mean response times for each group and stimulus type. Confidence interval for error bars: 95 %.


Group
Tinnitus
Control
Correct responses (%)
100
95
90
85
80
75
Congruent
Neutral
Incongruent
Switched task


Group
Tinnitus
Control
Response time (ms)
1300
1200
1100
1000
900
800
700
Congruent
Neutral
Incongruent
Switched task