Survey of tinnitus patients' acceptance of high-definition transcranial direct current stimulation as a management option

Running title: Tinnitus patients' acceptance of HD-tDCS

Authors: Tori Elyssa Kok MSc[1]; Rosemary Varley Ph.D.[2] Giriraj Singh Shekhawat Ph.D.[3,4,5];

Affiliations: [1] University College London, Ear Institute, London, United Kingdom; [2] University College London, Psychology and Language Sciences, London, United Kingdom; [3] Flinders University, College of Nursing & Health Sciences, Adelaide, Australia. [4] Honorary Professor, University College London, Ear Institute, UK. [5] Public Relations Manager, Tinnitus Research Initiative, Germany.

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Corresponding author: Name: Giriraj Singh Shekhawat; Address: Office – 7E524, College of Nursing & Health Sciences, Flinders University, GPO Box 2100, Adelaide, South Australia (SA) 5001; Mobile telephone number: +61 451 851 174; Business telephone number: +61 8 8201 8918; Fax number: +61 (08) 8204 5935; Business email address: giriraj.shekhawat@flinders.edu.au

Abstract

Objectives: To investigate acceptance of high-definition transcranial direct current stimulation (HD-tDCS) as a management option for tinnitus.

Design: Participants completed an online version of the Tinnitus Functional Index (TFI), after which they recorded their satisfaction ratings with different hypothetical intervention outcomes on a 10-point rating scale using Opinio survey software.

Study Sample: Data from 272 tinnitus sufferers from English-speaking regions worldwide were collected, of which the majority had moderate to severe tinnitus as per TFI.

Results: The survey showed that HD-tDCS was considered an acceptable form of tinnitus management, and that the satisfaction rating depended significantly on a number of factors: 1) the strength of the tinnitus reduction following the intervention ($p < 0.001$); 2) the duration of the intervention ($p < 0.001$); and 3) the effects of the intervention on either tinnitus loudness or tinnitus-related distress ($p < 0.001$). Respondents rated their satisfaction with the intervention 10/10 only if it completely eliminated tinnitus loudness, although reductions of 50-80% were also rated highly acceptable. No association was found between tinnitus severity and acceptability ratings.

Conclusions: These findings are important for future HD-tDCS trials for tinnitus, as they demonstrate the need to optimise stimulation protocols to increase effect sizes and decrease time spent on the treatment.

Key Words: tinnitus, non-invasive brain stimulation, tDCS, HD-tDCS, survey

Introduction

Tinnitus is the perception of a sound without an external source (1). Prevalence estimates of the condition vary across studies, for example 9.6% in US adults (2), 10-15% of the UK population (3) or as much as 20% - 30.3% in an elderly population in the Netherlands and Australia respectively (4, 5). It is commonly described as a ringing in the ears that, in 0.5% of the population, is experienced as extremely intrusive with severe impact on the quality of life (6). The prevalence of tinnitus is expected to increase due to an aging population (7) as tinnitus is twice as common in elderly individuals (8). There is currently no cure for tinnitus, but this is highly sought after by the tinnitus community.

Non-invasive brain stimulation techniques are under investigation for the management of tinnitus. Examples are transcranial direct current stimulation (tDCS) and its high-definition variant (HD-tDCS), which have been used as research tools to alter tinnitus loudness and tinnitus-related distress. In tDCS and HD-tDCS, electrodes are placed over the scalp, and a small electrical current is administered (9). Depending on the placement of the positive and negative electrode, stimulation can be anodal or cathodal. Anodal stimulation is thought to result in excitatory effects on underlying neurons through neural depolarization, whereas cathodal stimulation results in inhibitory effects through neural hyperpolarization (10).

Research efforts regarding tDCS have been ongoing since 2006 (11), and reviews of its efficacy for tinnitus show mixed results. Two systematic reviews with meta-analysis have been conducted. Wang et al. (12) included eight studies in their review and six in the meta-analysis and found that tDCS had a beneficial effect on tinnitus-related distress, but not on tinnitus loudness. By contrast, Song et al. (13) included six studies in their systematic review and two in the meta-analysis, and they reported a significant effect of tDCS on tinnitus loudness (mean reduction 13.5%), with 39.5% of participants showing a reduction in tinnitus loudness.

Shekhawat et al. (14) in a scoping review posed the question whether tDCS modulates tinnitus loudness or tinnitus-related distress. They included fifteen studies and found that tDCS resulted in a transient suppression of tinnitus loudness as well as tinnitus-related distress, and suggested the site of stimulation might affect these differentially. In a later scoping review, Kok et al. (15) grouped 38 tDCS studies according to three sites of stimulation to explore this hypothesis further. The three sites of stimulation used in tDCS research, in order of most often targeted to least often, were dorsolateral prefrontal cortex (DLPFC), left temporoparietal area (LTA), and auditory cortex.

The possibility that tDCS modulates affective dimensions of tinnitus rather than loudness is consistent with studies reporting effects of tDCS on other conditions with affective dimensions, such as depression and chronic pain (16). Most notably, stimulation of DLPFC has resulted in clinical benefits in the treatment of depression (17), suggesting DLPFC might be most effective in altering affective dimensions of tinnitus rather than its loudness. However, the scoping review by Kok et al. (15) found opposing results in this regard, of which two studies will be discussed.

Shekhawat and Vanneste (18) evaluated HD-tDCS of DLPFC for tinnitus in a double-blind randomized controlled trial of 13 participants. Using a cross-over design, they found that active HD-tDCS significantly improved tinnitus loudness, but not tinnitus-related distress, compared to sham HD-tDCS. By contrast, Faber et al. (19) administered conventional tDCS of DLPFC to 15 tinnitus sufferers, and found a significant improvement in tinnitus-related distress, but not loudness when comparing active and sham protocols.

An important question that arises, is: what do tinnitus sufferers think about non-invasive brain stimulation as a potential management option, and do attitudes differ depending on whether the intervention modulates tinnitus loudness or tinnitus-related distress? The two concepts do not have a straightforward relationship: the distress of tinnitus appears to be more related to the level of hearing

loss, the presence of hyperacusis and signs of depression, than to its actual loudness (8). For non-invasive brain stimulation to become a clinical management tool, it is important to investigate its acceptability for patients.

No patient surveys have been undertaken aimed at this goal as far as we know. A literature search was undertaken in PubMed and Web of Science Core Collection from inception to 18 May 2020, but no such survey was found. However, several surveys have looked at the acceptability of invasive brain stimulation and other types of tinnitus treatment. For example, Tyler (20) asked 197 self-help group attendees to rate *how willing* they were to undergo a certain treatment on a scale of 0 (not acceptable) to 100 (fully acceptable). In the analysis, an "acceptable" response was characterised as a rating between 91 and 100. Thirty percent of respondents rated external devices (similar to a hearing aid but producing sound or music) as acceptable if they reduced tinnitus loudness and tinnitus-related distress by half, and this increased to 42% if the reduction was complete. For pharmacological interventions, the respective percentages were 52% and 62%; for intracranial implants on the brain surface 13% and 21%; and for implants within the brain 13% and 19%. Tyler (20) also reported a significant positive correlation between the individual's tinnitus severity and their willingness to accept a treatment.

Engineer et al. (21) looked more deeply into the acceptability of tinnitus treatments, and replicated Tyler's findings. They conducted an online survey with 439 respondents. They analysed how willing patients would be to receive a treatment on a scale of 1 to 4 (1 = not willing at all; 2 = somewhat willing; 3 = willing; 4 = absolutely willing). They compared different therapies, with a focus on vagus nerve stimulation (VNS), in the scenario that the treatment reduced tinnitus-related distress by half, or completely eliminated tinnitus. The study showed 58.5% of the participants were willing to have a VNS device permanently implanted if it reduced their tinnitus by half, and this percentage increased to 82.4% if the elimination of tinnitus was complete. This study also replicated Tyler's finding that a daily pill was

the most acceptable form of intervention. It was again shown that patients who had very loud tinnitus were more likely to accept invasive treatments than patients with soft tinnitus.

Recently, Smit et al. (22) extended these findings by asking their 415 respondents to consider the potential side effects of three invasive procedures (cochlear implantation, deep brain stimulation and cortical stimulation), and with chances of the treatment being successful at either 50% or 100%. Participants rated their acceptance of these interventions on a scale of 0 – 10. Responses were grouped into three categories: “no acceptance” (0-4), “reasonable acceptance” (5-7), and “full acceptance” (8-10). The survey showed around 20% of participants were reasonably willing to undergo invasive treatment, and a further 20% were fully willing. They also found that people were more willing to undergo an invasive treatment if the chance of a cure was 100% instead of 50%. Smit et al. (22) also showed that mild side effects (e.g. temporary, non-bothersome) were acceptable to most patients, and severe side effects (e.g. chronic, bothersome) to almost half. However, deafness and death due to the invasive treatment as side effects were acceptable to only a small number of patients. Once again a small but significant positive correlation was found between acceptance ratings and tinnitus characteristics such as loudness, burden and awareness of tinnitus.

Synthesising the evidence presented above, a variety of invasive treatment methods were judged as acceptable by tinnitus sufferers, and people with severe tinnitus were the likeliest to accept invasive treatments. The success rate of the treatment and the potential side effects played a role in perceptions of acceptability, as well as the strength of the reduction (half or complete) of tinnitus. However, no survey sought opinions on non-invasive brain stimulation as a clinical management option. The surveys also did not compare possible outcomes beyond “reduce tinnitus by half” or “eliminate tinnitus completely”.

The current survey included multiple possible outcomes from HD-tDCS, as a range of effect sizes is observed in trials (12, 13). We also investigated the importance of whether tinnitus loudness is reduced following intervention, or the related distress. Furthermore, we examined the importance of the number of sessions necessary to establish the effect. As such, the current survey was undertaken to evaluate the acceptance of HD-tDCS, and respondents were asked to take into account the following factors: 1) the strength of the tinnitus reduction; 2) the importance of whether tinnitus loudness or tinnitus-related distress is reduced following intervention; and 3) the intervention duration.

Methods

This survey was an evaluation of the acceptance of HD-tDCS as a potential management option for tinnitus, involving prospective analysis of data collected from May to June 2020. The survey was fully anonymous and therefore individual consent was not sought. Nevertheless, approval by the UCL Research Ethics Committee was obtained to ensure compliance with the GDPR 2018 (project reference number: 17601/001).

Survey development

The survey was created in Opinio, a web-based survey tool from University College London. Only people with chronic tinnitus (i.e. more than 6 months) were asked to participate. The introduction page of the survey said: “You are invited to take part only if you yourself have experienced tinnitus or a "ringing in the ears" for 6 months or more. Please do not fill in the survey if you do not have tinnitus.” The survey consisted of three parts. Part 1 was a copy of the Tinnitus Functional Index (25 items) (23), to score the individual’s tinnitus severity. The TFI consists of rating scales of 0 – 10, or 0% - 100%. Part 2 consisted of hypothetical intervention scenarios and outcomes, and participants gave satisfaction ratings for each scenario (20 items). This part opened with a lay-person friendly explanation of what HD-tDCS is. Participants were told HD-tDCS involves placing a cap on their head with small electrodes in it, which

administers a small current to the brain. This could feel itchy or tingly. The recipient sits and relaxes during the stimulation, but they have to travel to a location (such as the university that carries out the research) on multiple occasions to receive the stimulation. Satisfaction ratings were probed on a scale of 0 (Not satisfied at all) to 10 (Extremely satisfied). An example question is:

> "Imagine you had to come in two times a week, for THREE WEEKS in a row, so SIX sessions in total. How satisfied would you be if your tinnitus LOUDNESS decreased by 30%?"

Part 2 was divided across two survey pages, with the first page detailing a scenario in which intervention duration was 6 sessions total (20 mins/session, 2 times/week, for 3 weeks). The second page detailed a scenario in which the intervention duration was 10 sessions total (20 mins/session, 2 times/week, for 5 weeks). Within these two survey pages, the scenarios in the questions varied in two ways. Firstly, in half of the scenarios, the brain stimulation was said to have an effect on tinnitus loudness, and in the other half only on tinnitus-related distress but not loudness. Secondly, five hypothetical strengths of the reduction of tinnitus loudness and tinnitus-related distress were used (10%/30%/50%/80%/100%).

In Part 3, open-ended questions were posed:

1. What do you think the direction of tinnitus research in the future should be?
2. What are your expectations for HD-tDCS as a tinnitus management option in the future?
3. What else (if anything) would you like us to know?

The open questions were analysed using a category system. The responses were analysed for common themes, resulting in a selection of categories, and subsequently assigned to these categories.

Survey distribution

The survey was open to responses for exactly one month in May – June 2020. The British Tinnitus Association (BTA) created a post on their website about the survey and circulated the link via their social media networks. The BTA is the largest charity for tinnitus sufferers in the UK. The survey link was also posted on Tinnitus Hub's "Tinnitus Talk" forum, a worldwide charity where tinnitus sufferers have an open forum for discussion.

Data management

Survey responses that were labelled as unfinished attempts in Opinio were deleted prior to data export. No questions were made obligatory in the survey, and therefore blanks were possible. For the overall TFI score to be valid, no more than 7 items were allowed to be omitted. Therefore, contributions that were missing more than 7 items of the 25 TFI questions were excluded (n = 2).

Data analysis

The TFI scores were analysed in Excel. The overall TFI score was calculated per participant by summing up all the valid answers (max. possible score = 250), dividing this number by the number of questions with a valid answer, and then multiplying by 10 (creating an overall TFI score between 0 – 100).

The satisfaction ratings were analysed in IBM SPSS Version 25. The primary outcome measure was the satisfaction rating on a scale of 0 – 10. Data were presented as means and standard deviations. Visual inspection of the data as well as the Shapiro-Wilks test indicated the data were not normally distributed. Therefore, non-parametric analyses were undertaken. The Friedman test was used for comparison between multiple repeated measures, and where significance was identified, this was followed up by a post-hoc two-tailed Wilcoxon signed-rank test. Spearman rank-order correlations were calculated for

the relationship between satisfaction ratings and the respondent's tinnitus severity. Bonferroni corrections were applied to $\alpha = 0.05$ for multiple comparisons.

Open questions in Part 3 were analysed using a code system for different types of responses and labelling the responses in Excel according to this code system.

Results

A total of 274 responses were exported from Opinio. Two responses were deleted because >7 items from the TFI were left blank, leaving 272 responses included in the analysis. The mean overall TFI score amongst the respondents was 55.59 (SD = 18.44). Table 1 shows the interpretation of TFI scores across five categories (24) with the respective frequencies in our survey sample.

TFI score range	Interpretation	Frequency in sample
0 – 17	Not a problem	n = 7
18 – 31	Small problem	n = 28
32 – 53	Moderate problem	n = 76
54 – 72	Big problem	n = 121
73 – 100	Very big problem	n = 40

Table 1 TFI scores in sample with categories

For the descriptive analysis, satisfaction ratings were classified into three categories based on Smit et al. (22): 0 – 4: "Low satisfaction"; 5 – 7: "Moderate satisfaction"; 8 – 10: "High satisfaction". For this analysis, results are presented by the strength of the hypothetical therapeutic effect. For each strength, the mean rating per participant for all survey questions was collated (e.g. mean satisfaction for a 10% reduction in either loudness or tinnitus-related distress following either 3 or 5 weeks intervention).

Figure 1 shows the percentage of respondents in each satisfaction category. High satisfaction (8 – 10) was found for 17% of respondents in the case of a 10% reduction, 24.1% for 30% reduction, 42.4% for 50% reduction, 68.8% for 80% reduction, and 79.6% for complete reduction.

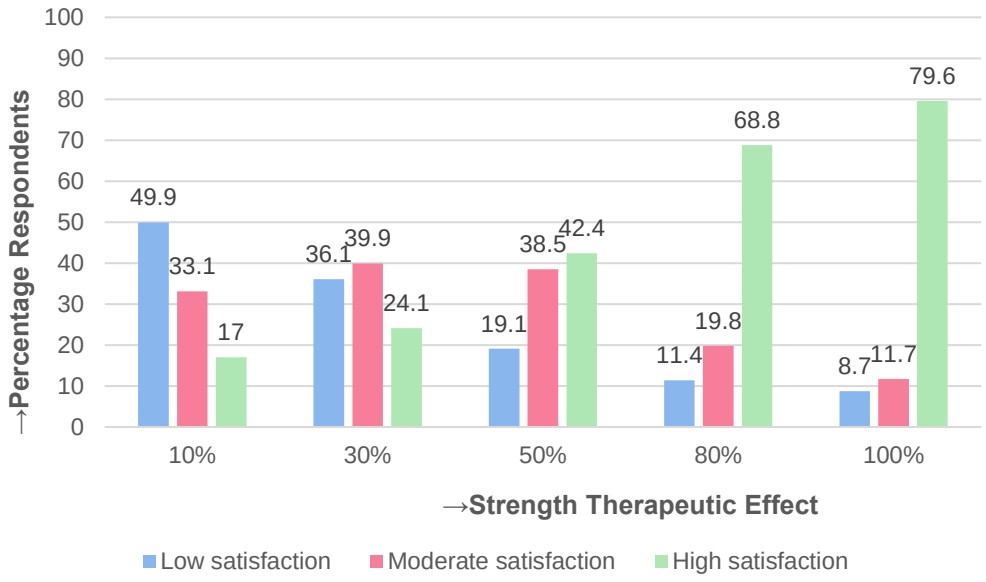

Figure 1 Percentage of respondents with low, moderate or high satisfaction by strength of therapeutic effect.

For the quantitative analysis, satisfaction ratings were split in two ways. First, the 3 weeks vs. 5 weeks intervention distinction was omitted, so as to only compare tinnitus-related distress and loudness modulation (see Figure 2). Then, the tinnitus-related distress and loudness distinction was omitted, to compare the effect of the duration of intervention (see Figure 3). The exact values (mean (SD)), and Z-scores with p-values, are presented in Table S1 in the supplementary materials.

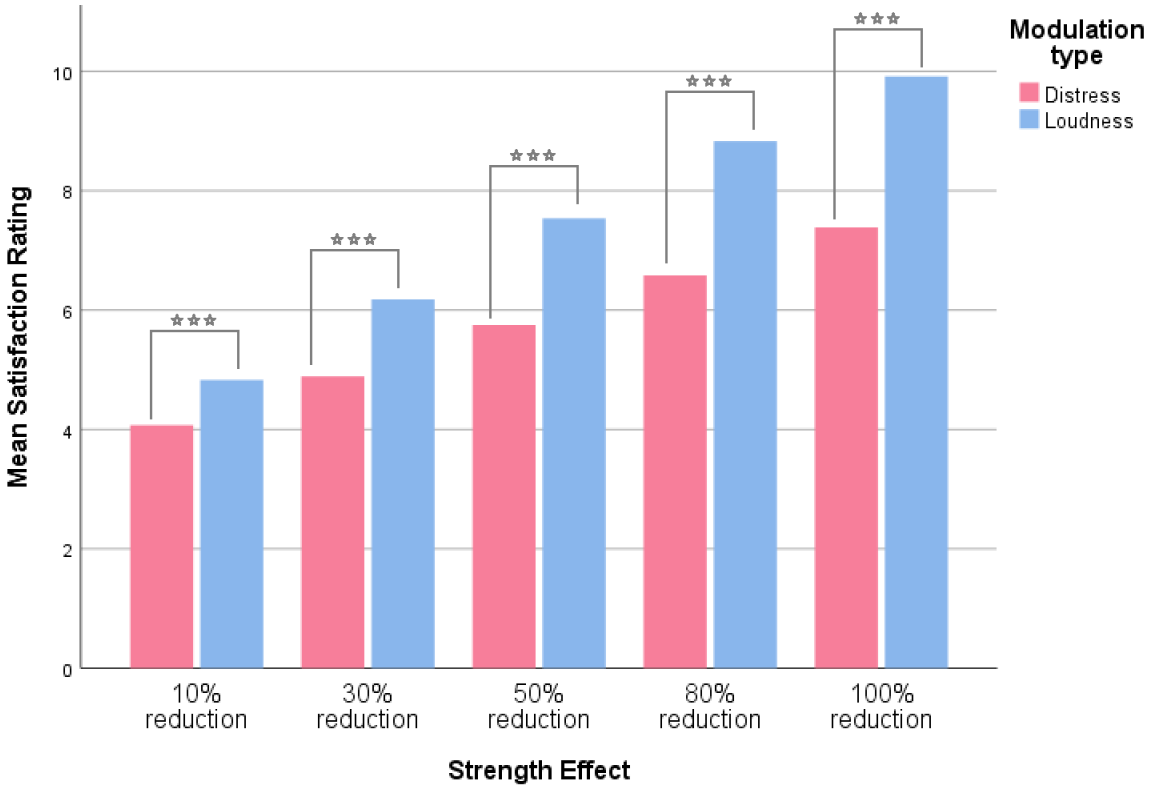

Figure 2 Mean satisfaction ratings by strength of therapeutic effect for loudness vs. distress reduction. Asterisks indicate a significant difference between loudness vs. distress reduction mean satisfaction ratings ($p < 0.001$, Bonferonni corrected $\alpha = 0.005$) calculated with the Wilcoxon signed rank test (see Table S1 for exact values). The Friedman test showed a significant difference in mean satisfaction ratings between all effect strengths for loudness and distress (not indicated in graph, see Table 2).

In the scenarios where HD-tDCS reduced tinnitus loudness, the Friedman test showed a significant difference in satisfaction ratings depending on the strength of the effect ($\chi^2(4) = 901.078$, $p < 0.001$). The post-hoc Wilcoxon tests showed a significant difference between all effect strengths (see Table 2).

In the scenarios where HD-tDCS reduced tinnitus-related distress, the Friedman test showed a significant difference in satisfaction ratings depending on the strength of the effect ($\chi^2(4) = 771.384$, $p < 0.001$). The post-hoc Wilcoxon test showed a significant difference between all effect strengths (see Table 2).

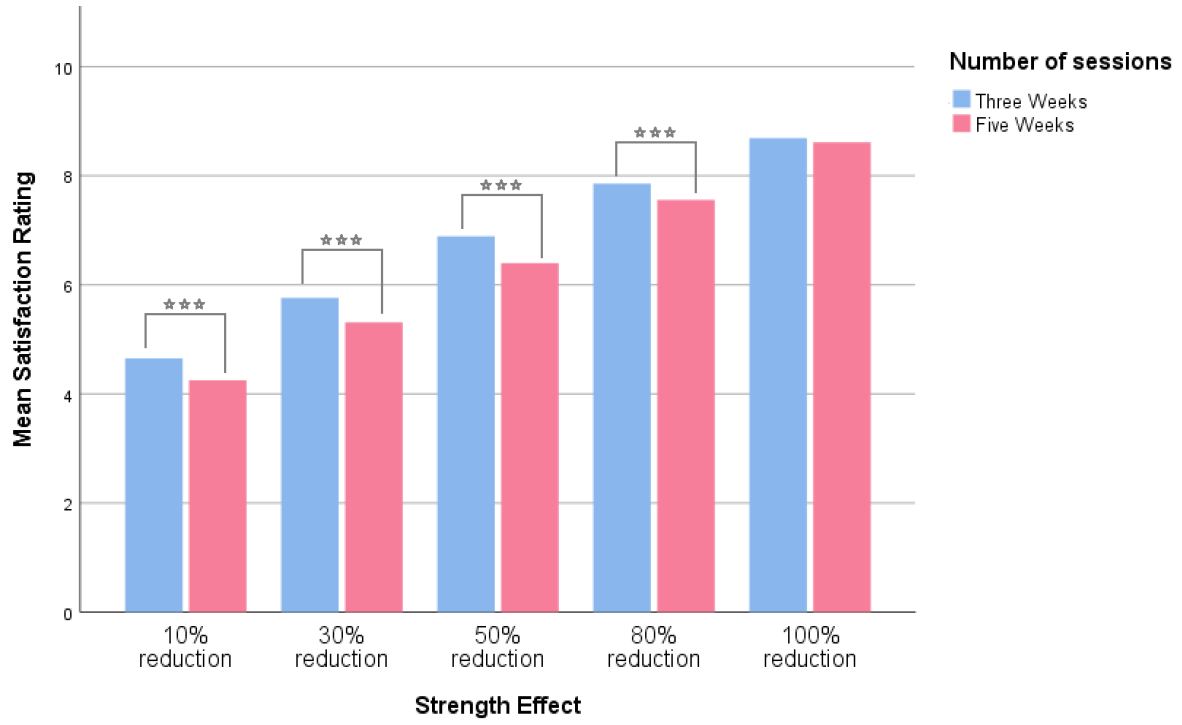

Figure 3 Mean satisfaction ratings by strength of therapeutic effect for 3 weeks vs. 5 weeks of stimulation. Asterisks indicate a significant difference between loudness and distress mean ratings ($p < 0.001$, Bonferonni corrected $\alpha = 0.005$) calculated with the Wilcoxon signed-rank test (see Table S1 for exact values). The Friedman test showed a significant difference in mean satisfaction ratings between all effect strengths for 3 weeks and 5 weeks (not indicated in graph, see Table 2).

With intervention duration at 3 weeks, the Friedman test showed a significant difference in satisfaction rating depending on the strength of the effect ($\chi^2(4) = 906.555$, $p < 0.001$). The post-hoc Wilcoxon tests showed a significant difference between all effect strengths (see Table 2).

With intervention duration at 5 weeks, the Friedman test showed a significant difference in satisfaction rating depending on the strength of the effect ($\chi^2(4) = 931.555$, $p < 0.001$). The post-hoc Wilcoxon tests showed a significant difference between all effect strengths (see Table 2).

Strength of therapeutic effect	Loudness modulation	Distress modulation	3 Weeks Intervention	5 Weeks Intervention
10% vs 30%	Z = -12.904 p < 0.001	Z = -11.564 p < 0.001	Z = -12.693 p < 0.001	Z = -12.654 p < 0.001
30% vs 50%	Z = -12.977 p < 0.001	Z = -11.923 p < 0.001	Z = -13.039 p < 0.001	Z = -13.002 p < 0.001
50% vs 80%	Z = -12.730 p < 0.001	Z = -11.381 p < 0.001	%: Z = -12.385 p < 0.001	Z = -12.896 p < 0.001
80% vs 100%	Z = -11.896 p < 0.001	Z = -10.788 p < 0.001	Z = -12.072 p < 0.001	Z = -12.171 p < 0.001

Table 2 Results of post-hoc Wilcoxon signed-rank tests comparing mean satisfaction ratings. A Bonferroni-adjusted alpha level of .003 was used (α = 0.05/16).

To analyse whether the respondent's tinnitus severity was associated with their satisfaction ratings, Spearman's rho-correlation coefficients were calculated. Table 3 shows Spearman's ρ, indicating no to weak correlations. There appeared to be a small significant correlation between tinnitus severity and the satisfaction rating in the case of a complete elimination of tinnitus loudness. Further examination of this correlation shows that satisfaction was almost unanimously 10/10 for complete elimination of tinnitus loudness, with a very small trend for respondents with less severe tinnitus to be less satisfied with complete elimination.

A post-hoc Spearman's correlation was calculated to investigate whether satisfaction with reduction in loudness might be correlated to the individual's tinnitus loudness rating rather than the total TFI score. One question in the TFI is: "Over the past week, on a scale of 0 to 10, how strong or loud was your tinnitus?" The correlations between responses to this question only and responses to questions about loudness reduction were weak and non-significant after Bonferroni adjustment.

			Respondent's tinnitus severity
Respondent's satisfaction rating	**Hypothetical scenario**		**Spearman's ρ**
	Loudness reduction	10%	0.076
		30%	0.035
		50%	0.026
		80%	0.002
		100%	0.185*
	Distress reduction	10%	0.063
		30%	0.068
		50%	0.046
		80%	0.049
		100%	0.081
	3 weeks intervention	10%	0.066
		30%	0.031
		50%	0.03
		80%	0.04
		100%	0.08
	5 weeks intervention	10%	0.083
		30%	0.066
		50%	0.048
		80%	0.065
		100%	0.105

*Table 3 Spearman rho-correlation coefficients of the relationship between satisfaction ratings of the hypothetical intervention outcomes and respondent's tinnitus severity. An asterisk * indicated $p < 0.0025$ according to Bonferroni adjustment ($\alpha = 0.05/20$).*

Regarding the third part of the survey, the open-ended question on the future direction of tinnitus research resulted in 245 responses. The responses were coded into six different types of answers shown in Figure S1 (see Supplementary). The majority of participants replied they expect future research to focus on finding a complete cure for tinnitus (31%). Others said research should aim to reduce the loudness (14%), or should simply find anything that can manage tinnitus (10%).

The second question was about expectations of HD-tDCS as a future management option. The question was answered by 247 respondents and responses were coded in Figure 4. Most respondents were optimistic (31%) or open-minded (28%) towards trying it. People who were sceptical or hopeful with caution (12%) mentioned they were concerned with how it could become widely available in healthcare services.

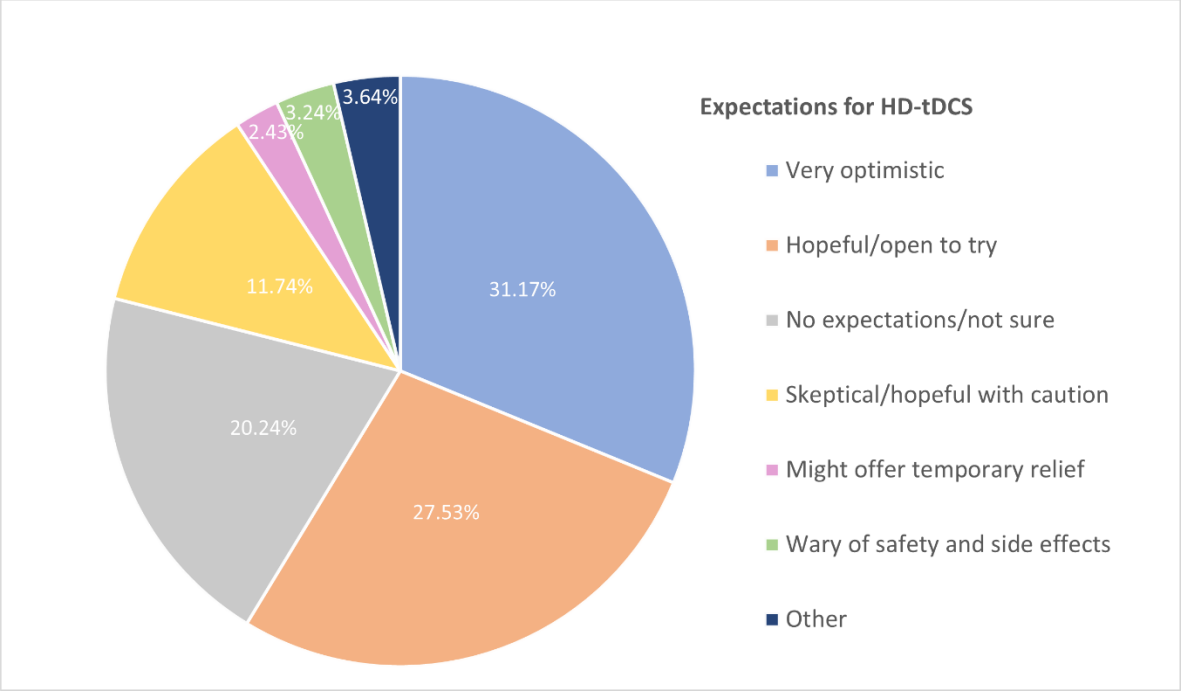

Figure 4 Types of answers to the question: "What are your expectations for HD-tDCS as a tinnitus management option in the future?"

The final question was: "Is there anything else you would like us to know?" A total of 145 responses were given to this question, coded in Figure S2 (see Supplementary). Most people (38%) used this free space to share more information about their personal situation and experience of tinnitus, or what they believed caused it for them. Ten percent of respondents also expressed interest in participating in an HD-tDCS trial.

Discussion

This survey investigated the acceptability of HD-tDCS as a management option for tinnitus. The results showed that most tinnitus sufferers consider it to be an acceptable management option. Unsurprisingly, the acceptability was shown to be strongly influenced by the strength of tinnitus reduction following stimulation, with average satisfaction ratings reaching high levels (score of 8 – 10) when the hypothetical reduction was 80% or more. Moderate satisfaction (5 – 7) was found for reductions of 30% or more.

Satisfaction ratings were also influenced by whether the intervention affected tinnitus loudness or tinnitus-related distress. Respondents reported higher satisfaction if the tinnitus loudness was reduced following intervention rather than the tinnitus-related distress. This survey showed that, even if the distress reduction was 100%, mean satisfaction ratings were still not high (8 – 10). This is an important finding as a number of intervention studies using tDCS for tinnitus found only an effect on tinnitus-related distress (15). One systematic review with meta-analysis also found only an effect on tinnitus-related distress but not loudness (12). Therefore, it is key for future tinnitus intervention research to focus on reducing the tinnitus loudness rather than related distress. This finding also illustrates the need to not only include as outcome measures Visual Analogue Scale (VAS) loudness measurements, but also psychoacoustic measurements such as minimum masking level (MML) and tinnitus loudness and pitch matching tasks. This is important because VAS loudness measurements rely on self-reporting and are correlated to self-reported VAS distress measurements, whereas psychoacoustic loudness measurements are not, raising the concern that VAS loudness measurements reflect reactions to the tinnitus rather than its pure loudness perception (25-27).

Another factor that affected satisfaction ratings was the proposed time spent on the stimulation sessions. Participants were more satisfied overall if the intervention duration was six sessions rather than ten sessions. However, if the stimulation could completely eliminate the tinnitus, this significant difference disappeared, suggesting respondents would be just as open to attending ten sessions in this case.

Interestingly, the present survey did not find an effect of tinnitus severity on satisfaction ratings. Previous surveys looking at invasive brain stimulation (20-22) consistently found that people with very severe tinnitus were more likely to accept invasive treatments than people with milder tinnitus. In the present survey, there was no evidence for a correlation between Tinnitus Functional Index scores and

the mean satisfaction ratings for all reduction strengths, whether tinnitus loudness or tinnitus-related distress was modulated or whether the intervention was three or five weeks. The one exception was a small but significant correlation between satisfaction ratings in the case of a 100% reduction of tinnitus loudness, in which case it was shown that a higher tinnitus severity score was associated with a higher satisfaction rating.This could reflect that people with severe tinnitus are more eager for a "total cure" than people with mild tinnitus.

Three explanations can be offered for the lack of association between tinnitus severity and acceptability ratings in this survey compared to the aforementioned surveys. It could be due to the invasive nature of the treatments described in the other surveys. People with less severe tinnitus might be less willing to undergo invasive treatments than people with severe tinnitus, but this difference might disappear for non-invasive treatments as people with mild tinnitus might be just as willing. A second factor might be the manner in which questions were framed in the surveys. This survey posed a different question, focusing on *how satisfied* tinnitus sufferers would be with a certain outcome rather than *how willing* they would be to undergo the treatment. It might be that satisfaction with the treatment outcome is not correlated to tinnitus severity in the same way. Finally, it could be that the present survey did not identify a correlation between tinnitus severity and satisfaction ratings because the sample's tinnitus severity was heavily centred around moderate to severe tinnitus. The lack of a range of different tinnitus severities could mean a lack of different responses which would make it difficult to detect any correlation.

The reason for framing the question around satisfaction was because generally, tinnitus sufferers are highly motivated to try anything that could help them. This "open to anything" approach may apply less to invasive treatments, but it could apply to HD-tDCS, which is considered safe with minor, transient side effects such as tingling and in few occasions mild scalp burns. This survey only mentioned tingling or

itching under the electrodes, although it would have been preferable to have given more information on side effects. Using satisfaction ratings was an attempt to avoid finding relatively high ratings due to "I will try anything" approaches. However, this makes it more difficult to directly compare our results to other acceptability surveys.

Nevertheless, some comparisons can be made, and the results reveal commonalities with previous surveys. For example, Engineer et al. (21) reported that over half of the tinnitus sufferers in their survey were willing to have a vagus nerve stimulator (VNS) permanently implanted in their body, even if it only reduced their tinnitus by half. The present survey also found that a half-reduction of tinnitus was highly satisfactory for 42.4% of respondents.

It should be mentioned that tinnitus reductions in either loudness or distress of 50% or more are not currently found on a consistent basis in non-invasive brain stimulation trials. Effect sizes tend to be smaller, and the systematic review and meta-analysis reported by Song et al. (13) found a mean loudness reduction of 13.5%. The present survey showed that for a 10% reduction, 49.9% of participants would not be satisfied, 33.1% would be moderately satisfied, and 17% would be highly satisfied (as demonstrated in Figure 1). Therefore, it is important to manage expectations of participants in trials appropriately, while in parallel researchers work on optimising therapeutic effects.

The open-ended questions confirmed the aspiration for large loudness reductions found in the satisfaction ratings analysis. Fourteen percent of respondents said research should focus on finding treatments that can reduce loudness, and 31% wanted a complete cure. On HD-tDCS in specific, over half of the respondents said they were optimistic or willing to try it.

On a final note, the present survey has a number of limitations. First, one might argue that the questions were presented in a suggestive way. By having the questions presented in a cumulative fashion running up from 10% to 100% reduction, people might have been inclined to adjust their ratings in similar linear

fashion. It may have been beneficial to either randomise the order of these questions, or to present the questions on separate survey pages rather than immediately below each other, to make this incline in reduction less obvious. However, it is still fair to assume that the strength of the therapeutic effect of the intervention is important to the tinnitus sufferer's satisfaction.

Second, because this survey was conducted anonymously, no sample characteristics were obtained. It would have been preferable to have had information about age, sex, duration of tinnitus, laterality of tinnitus, and accompanying hearing loss. However, Smit et al. (22) showed that correlations between these characteristics and acceptability were either weak or absent.

Third, it would have been useful to include a question in the survey about people's previous experiences with non-invasive brain stimulation to understand their prior perceptions about this management option. Future surveys investigating the acceptability of HD-tDCS would also benefit from including a direct comparison with other intervention strategies such as different non-invasive brain stimulation techniques or a daily pill.

Conclusion

The present survey found that tinnitus sufferers consider HD-tDCS an acceptable management option. Mean satisfaction ratings could be classified as high when the strength of tinnitus loudness reduction following intervention was >80%. However, subgroups of respondents also reported high satisfaction starting from 10% reduction. Future HD-tDCS studies should focus on increasing loudness reduction following stimulation.

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Supplementary Tables and Figures

Strength of therapeutic effect	Type of Modulation			Duration of Intervention		
	Loudness	Distress	p-value	3 Weeks	5 Weeks	p-value
10%	4.83 (2.90)	4.06 (2.93)	Z = -6.695 p < 0.001	4.65 (2.74)	4.26 (2.92)	Z = -6.381 p < 0.001
30%	6.18 (2.47)	4.89 (2.89)	Z = -9.701 p < 0.001	5.76 (2.44)	5.31 (2.69)	Z = -7.176 p < 0.001
50%	7.54 (1.89)	5.74 (2.88)	Z = -11.204, p < 0.001	6.90 (2.14)	6.38 (2.32)	Z = -8.163 p < 0.001
80%	8.83 (1.23)	6.57 (2.97)	Z = -11.795 p < 0.001	7.85 (1.83)	7.57 (1.97)	Z = -5.861 p < 0.001
100%	9.91 (0.59)	7.40 (3.11)	Z = 11.163 p < 0.001	8.69 (1.63)	8.61 (1.68)	Z = -2.480 p = 0.013

Table S1 Mean (SD) satisfaction ratings by strength of therapeutic effect, type of modulation, and duration of intervention. The Wilcoxon signed-rank test was used with a Bonferroni-adjusted alpha level of 0.005 (α = 0.05/10).

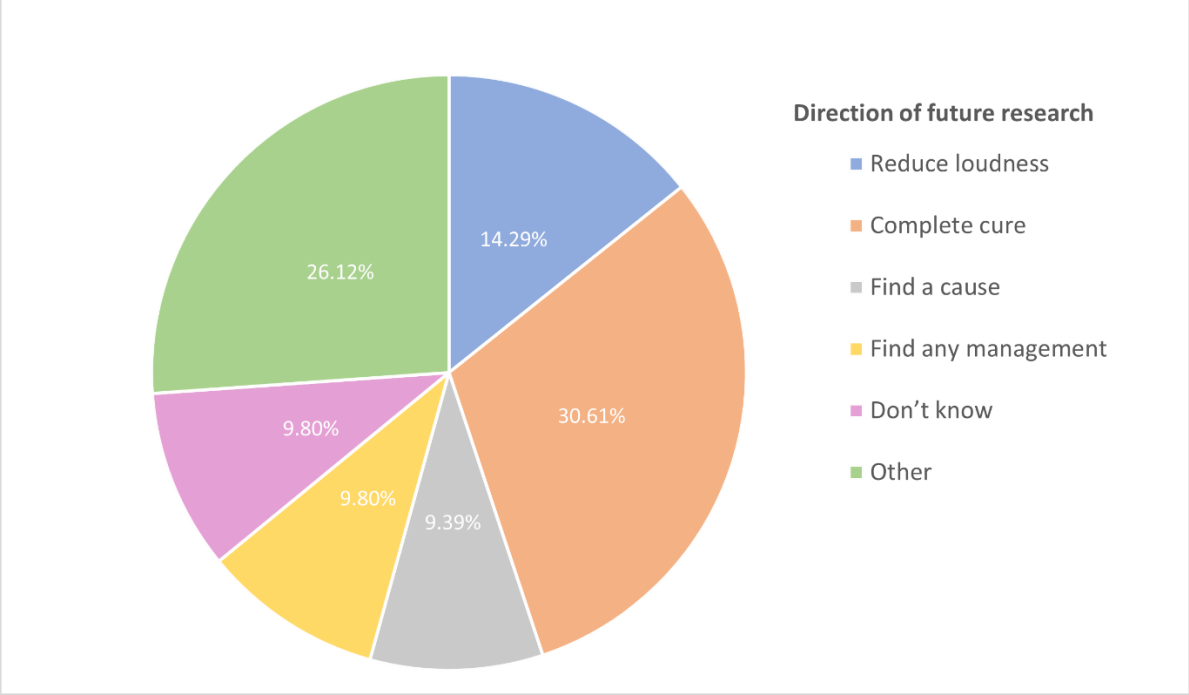

Figure S1 Types of answers to the question: "What do you think the direction of tinnitus research in the future should be?"

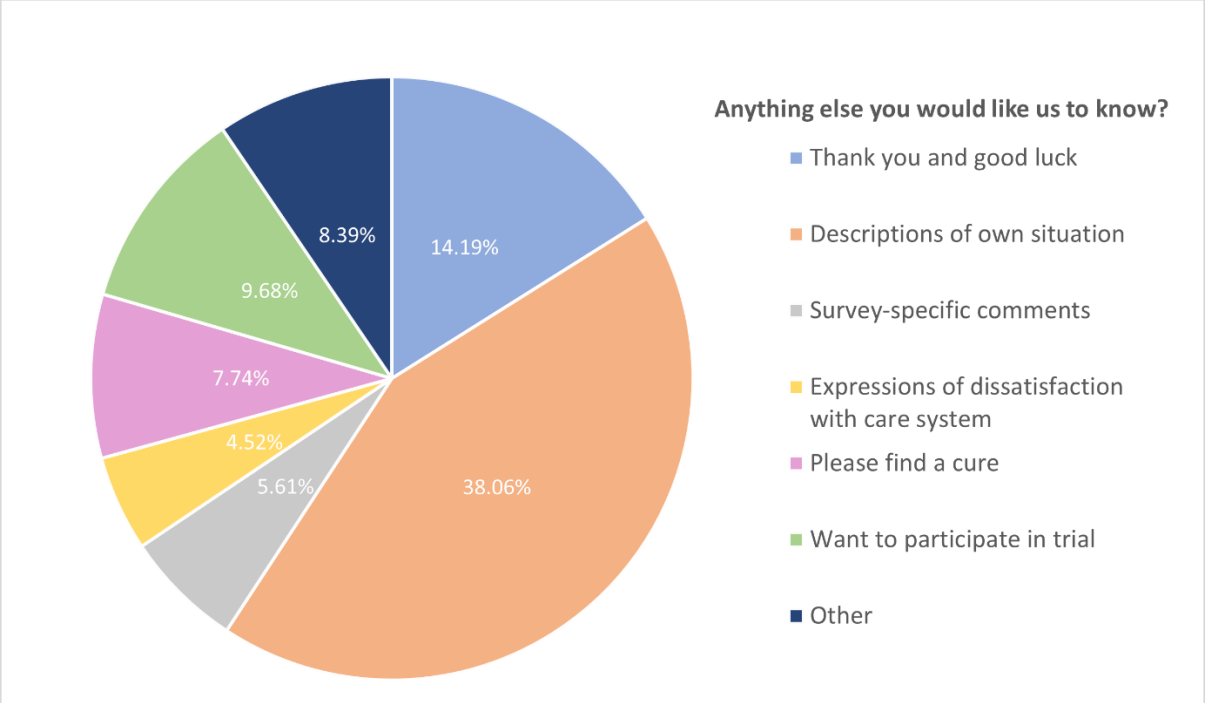

Figure S2 Types of answers to the question: "Is there anything else you would like us to know?"