## Evaluation of a Cognitive Behavioural Model of Tinnitus Distress: A cross-sectional study using structural equation modelling

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## Abstract

#### Objectives

There is a great deal of variation in the extent to which people with tinnitus find it distressing, which cannot be explained solely by differences in perceived loudness. The Cognitive Behavioural Model of Tinnitus Distress proposes that tinnitus becomes and is maintained as a distressing problem due to a process of interaction between negative thoughts, negative emotions, attention and monitoring, safety behaviour and beliefs. This study used path analysis to assess how well different configurations of this model fit using questionnaire data obtained from people with tinnitus.

#### Design

This was a cross-sectional study. Three hundred and forty two members of the public with tinnitus volunteered to complete a survey comprising a series of questionnaires and subscales of questionnaires measuring each of the constructs contained within the Cognitive Behavioural Model of Tinnitus Distress. The optimum factor structure of each measure for the study population was established and the resulting factors were used to construct a series of path models based on the theoretical model. Path analysis was conducted for each of these, and the goodness of fit of the models was assessed using established fit criteria.

#### Results

Five of the six path models tested reached the threshold for adequate fit and further modifications improved the fit of the three most parsimonious of these. The two best fitting models had comparable fit indices which approached the criteria for good fit (RMSEA= 0.061, CFI=0.984, TLI= 0.970 and RMSEA=0.055, CFI=0.993, TLI=0.982.) They differed principally in the placement of tinnitus magnitude and the inclusion/ non-inclusion of control beliefs.

#### Conclusion

There are theoretical arguments to support both a beliefs-driven and a loudness-driven model, and it may be that different configurations of the Cognitive Behavioural Model of Tinnitus Distress are more appropriate to different groups of people with tinnitus. Further investigation of this is needed. This notwithstanding, the present study provides empirical support for a model of tinnitus distress which provides a clinical framework for the development of more effective psychological therapy.

## Introduction

A consistent finding in tinnitus research is the large degree of variation in the extent to which people are troubled by the experience of noises in their ears. Davis and El Refaie (2000) reported that only half of respondents reporting tinnitus in a UK- based survey rated it as either moderately or severely annoying. Data collected from the UK Biobank suggests a quarter of people aged 40-69 said they were moderately or severely upset by their tinnitus, with the remainder rating it as slightly bothersome or not bothersome at all (McCormack et al. 2014). Similar findings have been reported in Japan (Michikawa et al. 2010), Norway (Krog, Engdahl, & Tambs, 2010) and Poland (Fabijanska, Rogowski, Bartnik, & Skarzynski, 1999). Those who are troubled by their tinnitus may find it very distressing indeed (Andersson et al. 2005; Pridmore, Walter, & Friedland, 2012) and a number of researchers have attempted to identify what factors might account for a perception of noise in the head being an untroubling experience with no consequences to one person and a catastrophe affecting every aspect of life to another (McCombe et al. 2001). Although it might be assumed that the louder the noise is, the more distressed the person perceiving it is likely to be, this assumption is not supported by studies which have shown only weak correlation between tinnitus loudness and tinnitus-related distress (Cope, Baguley, & Moore, 2011; Degeest et al. 2016; Hoekstra, Wesdorp, & van Zanten, 2014). Hallam et al. (1984) were the first to give central prominence to psychological reaction to tinnitus as a moderator of distress in a psychological model of tinnitus. Since then, a number of other attempts have been made to explain the internal processes that may lead to tinnitus becoming persistently troublesome. McKenna (2004), in keeping with Hallam et al. (1984), proposed that a conscious thought process triggers a chain of events that maintains tinnitus distress. This is congruent with current thinking about how psychological distress is maintained across a range of long-term health conditions by an interaction between negative cognition, emotion and behaviour. Specifically, McKenna et al. (2014) proposed a Cognitive Behavioural Model of Tinnitus Distress (shown in figure 1) based on the Model of Insomnia proposed by (Harvey, 2002). McKenna et al. suggest that thinking of tinnitus in a negative way leads to feelings of distress, which in turn draws more attention towards the tinnitus and may cause the perception of it to be distorted. Increased attention fuels further negative thoughts, while underlying beliefs and changes in behaviour (eg avoiding previously enjoyed situations for fear of making tinnitus worse) further enhance negative thinking, which increases distress, and so the cycle continues. McKenna’s model seeks to explain the maintenance not of tinnitus perception but of tinnitus- related emotional distress. While eliminating the tinnitus percept is currently rarely possible, reduction of tinnitus distress is both possible, highly desirable to sufferers, and the object of psychological intervention (McKenna & Andersson, 2008).

\*\*insert figure 1 here\*\*

Figure 1: Cognitive Behavioural Model of Tinnitus Distress; reproduced from [McKenna et al. (2014](#_ENREF_37))

Unlike many models of tinnitus, one advantage of this model is that it can be subjected to scientific testing, although this has not yet been done for the model in its entirety. Several previous studies which have investigated the question of how tinnitus becomes a distressing problem have used multiple regression analysis to assess the degree to which a number of independent variables (such as depression, anxiety and insomnia) explain the variance in a dependent variable, such as tinnitus distress or quality of life (Langenbach et al. 2005; Oishi et al. 2011; Zeman et al. 2014). However, multiple regression analysis on its own is not sufficient for testing all the relationships suggested in the Cognitive Behavioural Model of Tinnitus Distress as there are multiple independent and dependent variables. This model does not simply postulate that thoughts, behaviour, attention etc all contribute to the experience of tinnitus distress. Rather, it predicts that all these components interact directly and indirectly in specific ways on the outcome of tinnitus distress. Here we have used Structural Equation Modelling to test these predictions in one model. The aim of this study was to investigate whether the predicted relationships between components of the theoretical model (McKenna et al. 2014) are empirically supported.

## Materials and Methods

#### Ethical approval

Approval for this study was granted by the University of Nottingham Research Ethics Committee (Faculty of Medicine and Health Science) in February 2014. Reference: G13022014.

#### Participants

The study sought to recruit a representative sample of people who have tinnitus. The primary inclusion criteria were having had tinnitus for more than two months (to exclude short- term tinnitus related to noise exposure, blocked ears and so on) and being aged 18 or older. Exclusion criteria were being unable to understand written English and being unable to read text in print or on a computer screen.

Participants were recruited from a research participant database held by the National Institute for Hearing Research (NIHR) Nottingham Biomedical Research Centre (BRC) and via the British Tinnitus Association (BTA) in its members’ magazine (‘Quiet’), on its website and on social media (Facebook and Twitter). Reminders about the study were posted on the BTA Facebook page periodically. In addition, the study was advertised on a forum run by Hearing Link (an organisation for people with hearing loss) and by personal contacts.

To test a model that can account for the range of tinnitus experience, it is important to recruit participants who span the full spectrum of tinnitus symptom severity. A target was set to recruit into each of five problem categories. Our categories were derived from a tinnitus problem scale used by Meikle et al. (2012) which asks the question: “How much of a problem is your tinnitus?” We aimed to recruit the following proportion of participants for each of the five response categories: not a problem: 10%, a small problem: 25%, a moderate problem: 30%, a big problem: 25%, and a very big problem: 10%. These targets were based on the proportion of participants falling into each category from no distress to high distress on the Tinnitus Research Initiative database (Zeman et al. 2012). Once a response category had reached its recruitment target, we declined further offers of participation from people who fell into that category.

#### Measures

Seven instruments were compiled into a survey. One instrument was chosen to measure each of the seven components of the model. Instruments were selected according to their construct validity, internal reliability, and the time it takes participants to complete them. It was also important to ensure that each measure was relevant to just one component of the model and avoided conceptual overlap with other measures to allow the Cognitive Behavioural Model of Tinnitus Distress as outlined in McKenna et al. (2014) to be tested. For this reason, established alternatives which are multi-dimensional, such as the Tinnitus Handicap Inventory and the Tinnitus Functional Index, were not chosen.

Negative Automatic Thoughts

The Tinnitus Cognitions Questionnaire (TCQ; Wilson & Henry, 1998) was chosen to assess the content and frequency of thoughts participants have in relation to their tinnitus. Respondents are asked to indicate how often they have been aware of thinking a particular thought using a 5-point Likert scale with the anchors: ‘never’ and ‘very frequently.’ The TCQ consists of two separate subscales comprising 13 items each dealing with positive (e.g. “there are things in life worse than tinnitus”) and negative (e.g. “why me? Why do I have to suffer this horrible noise?”) thoughts relating to tinnitus. We found the original, two-factor solution (negative and positive thoughts) to be an adequate fit to the data (Handscomb et al. 2017).

Arousal and Emotional Distress

The questionnaire chosen to measure generalised arousal and emotional distress was Clinical Outcomes in Routine Evaluation (CORE-OM, Evans et al. 2000). It is intended as a measure of global distress and it includes items that pertain both to mental processes and to feelings of autonomic arousal. The CORE-OM contains 34 items. Respondents indicate how much each item has applied to them over the past week, using a 5-point Likert scale with the anchor points ‘not at all’ and ‘most or all of the time.’ Although the CORE-OM was originally divided into four subscales, we found the three-factor solution proposed by Evans et al. (2002) to be a better fit to the data, with the three factors being positive emotions, negative emotions and risk of harming oneself or others (Handscomb et al. 2016). Examples of items pertaining to these are: “I have felt optimistic about my future”, “I have felt despairing or hopeless” and “I have made plans to end my life”, respectively.

Selective Attention and Monitoring

The Tinnitus Vigilance and Awareness Questionnaire (TVAQ; Cima, Crombez, & Vlaeyen, 2011) measures the extent to which people attend to their tinnitus in everyday life. Its 18 items cover both selective attention and monitoring behaviour. Respondents are asked to indicate how often each statement applies to them using a 6-point Likert scale with the anchor points ‘never’ and ‘always.’ Although the original TVAQ was presented as a unifactorial measure, its authors did not carry out exploratory factor analysis to confirm this. When we carried out exploratory factor analysis, a four-factor solution was found to be the best fit to our data (Handscomb, 2018). The four factors were: awareness of changes in tinnitus, preoccupation with tinnitus, monitoring behaviour and ability to ignore tinnitus. Items on the preoccupation subscale imply a sense of being unable to shift attention away from tinnitus, while items on other subscales of this questionnaire deal with more active behavioural processes (such as checking up on tinnitus.)

Safety Behaviour

The Tinnitus Fear Avoidance Scale (TFAS) was developed to measure avoidance behaviour related to tinnitus (Kleinstauber et al. 2013). It contains 15 items with which respondents indicate their agreement on a 6-point Likert scale with the anchor points: ‘strongly disagree’ and ‘strongly agree.’ Principal components analysis identified 3 factors: cognitions, tinnitus- related avoidance and ear- related avoidance. There is considerable overlap between the four items on the cognitions subscale of the TFAS and the TCQ; therefore it was decided to use the two avoidance subscales only, as a more specific measure of safety behaviour. This modified, 2-factor version of the questionnaire (TFAS-M) was found to be an adequate fit to the data in this study (Handscomb, 2018).

Beliefs

Part of the Illness Perception Questionnaire (IPQ; Moss-Morris et al. 2002) was selected to measure tinnitus-related beliefs. It is a 38- item questionnaire with seven subscales designed to measure illness representations across a range of health conditions. Responses are given on a 5-point Likert scale with the anchor points ‘strongly disagree’ and ‘strongly agree’ and higher scores indicate a more positive outlook. Two of the subscales included in the IPQ deal with control beliefs (‘personal control’ and ‘treatment control’). A modified two-factor version of the IPQ (IPQ-M) using these control subscales was shown to be an adequate fit to the data in the current study (Handscomb, 2018).

Distorted perception

The Tinnitus Magnitude Index (TMI; Schmidt et al. 2014) was used as an indirect measure of tinnitus ‘size’, independent of the reaction to it. It contains 3 items to be rated on a numerical scale of 0-10. As a 3-item scale this measure could not be subject to full confirmatory factor analysis, but high internal consistency (α=0.921) was found (Handscomb, 2018).

Tinnitus- related Distress

The 26- item Tinnitus Reaction Questionnaire (TRQ; Wilson et al. 1991) was chosen to measure tinnitus-related distress as it was designed explicitly for this purpose. It consists of 26 items rated on a 5-point Likert scale with the anchor points ‘not at all’ and ‘almost all of the time.’ In the current study a single-factor solution was the best fit to the data (Handscomb, 2018).

\*\*insert table 1 here\*\*

#### Sample size

A power calculation was conducted using methods recommended by MacCallum et al. (1996) and was based on 80% power, an anticipated effect size of 0.3, alpha 0.05 and conservative degrees of freedom of 38. It indicated that 320 individuals were required to test the model using SEM techniques.

#### Study procedure

On receipt of a completed consent form, we either emailed the participant with a link to the survey and an automatically generated password or posted a paper copy of the survey to them with a stamped, addressed envelope for return, according to preference. Participants who had completed a consent form but had not completed the full survey 4 to 6 weeks later were sent a reminder. The survey was available for completion for 7 months.

As well as completing the survey, all participants were asked to complete the tinnitus problem scale (Meikle et al. 2012) described earlier. They were also asked for demographic information and brief details of their experience with tinnitus. Two free text boxes were provided at the end of the survey, one for comments about the survey itself and the other for any additional comments about the respondent’s tinnitus.

#### Data analysis

The data were analysed using MPlus software version 7.2 (Muthen and Muthen, 2005-2014). First, factor analysis was carried out for each of the questionnaires/ subscales selected in order to establish the factor structure of each that best fit the population to be tested, and the factor scores saved.

The Cognitive-Behavioural Model of Tinnitus Distress was then reconfigured in order to be testable using SEM; that is, mapping both direct and indirect influences of several predictor variables on a single outcome variable. Two models which include the same set of variables in a different configuration may result in very different fit statistics, so it is important to carefully consider which components are candidates to be exogenous variables and which variables are likely to mediate between others. It is possible to test a whole series of models with variables connected in multiple different ways, but it is important for decisions about configuration to be based on theory and existing evidence. In this case, the (re)configuration process resulted in a series of path models, with each measured variable contained within a factor score (from the factor analysis).

In each model, tinnitus-related distress (measured by the TRQ) was the outcome variable. Beliefs (measured by the IPQ-M) was selected as the exogenous variable. However, because the correlation between scores on the TRQ (measuring tinnitus-related distress) and the IPQ-M was found to be very weak (r=-0.271), while it was strong between the TRQ and all other measures used in the survey (r=0.666-0.788), we decided to test versions of the model both with and without control beliefs and to observe whether omission of this construct improved or worsened model fit. Without beliefs as the driver, negative thoughts (measured by the TCQ) become an exogenous variable. In cognitive behavioural therapy, negative thoughts are seen as a trigger for emotional distress and safety behaviour (Beck et al. 1979) and so their position as an exogenous variable seems reasonable.

Another potential exogenous variable was tinnitus magnitude, which may be influenced by factors outside the model, such as the degree of hearing loss. Placing it in as an exogenous variable which influences attention and monitoring, would see magnitude as the ‘driver’ of the ensuing psychological process. Such a configuration is further removed from the original, theoretical model, but equally plausible.

Given that there is no strong empirical reason to favour one configuration over the other, it was decided to test two sets of structural models (both of which had tinnitus distress as the outcome variable). The first set (models 1-3) broadly followed the configuration of the original, theoretical model, with magnitude being predicted by attention and monitoring (see figure 2). The second set (models 4-6) departed further from the configuration of the original, theoretical model, having magnitude as an exogenous variable and attention and monitoring being predicted by magnitude (see figures 3 and 4).

Goodness of fit of each entire model was judged using two types of fit indices. Absolute fit indices compare the data to an estimated model, which is predicted by the MPlus program using the data, error calculations and various constraints indicated by the user. Comparative fit indices compare the data to a baseline or null model, in which there is no response pattern. The absolute fit index used was the Root Mean Square Error of Approximation (RMSEA; Steiger, 1990), reported with 90% confidence intervals. The comparative fit indices were the chi square, the Comparative Fit Index (CFI; Bentler, 1990) and the Tucker Lewis Index (TLI; Tucker & Lewis, 1973). Inspection of factor scores indicated that they were not normally distributed for all of the factors used. Therefore, the estimator chosen for path analysis was Maximum Likelihood with Robust Standard errors and χ2, known as MLM, as its use of the Satorra-Bentler χ2 statistic hasbeen shown to perform well with non-normally distributed continuous data (Curran, West, & Finch, 1996) and it is also appropriate for use with small to medium sample sizes (Asparouhov, 2005).

For the RMSEA, a value of less than 0.05 was taken to represent good fit, a value of up to 0.08 was considered an acceptable absolute fit (Joreskog & Sorbom, 1993), and a RMSEA of between 0.08 and 0.1 was considered a mediocre fit (MacCallum et al. 1996). The chi- square should ideally be non-significant (i.e p>0.05; Byrne, 2012). For both the CFI and TLI a value of >0.95 indicates a good fit (Hu & Bentler, 1999).

Modification Indices were also provided by MPlus. These indicate changes in parameters which, if implemented, would improve the fit of the model. The structure of the model may be amended according to the modification indices in order to produce a better fit, but only if such changes can be supported by theory (Byrne, 2012; Schumacker & Lomax, 2004).

#### Path analysis

In each path model, all subscales were assumed to covary with other subscales which formed part of the same questionnaire except for the two subscales of the TCQ (negative and positive thoughts), which were shown to be uncorrelated (Handscomb et al. 2017).

Model 1 adhered as closely as possible to the Cognitive Behavioural Model of Tinnitus Distress (McKenna et al. 2014), within the confines of structural equation modelling (see figure 2). The exogenous variables in this model are personal control beliefs and treatment control beliefs (measured by the two subscales of the IPQ-M). Model 1 assumes that attention and monitoring (measured by the TVAQ) predict magnitude (measured by the TMI). It also assumes that attention and monitoring mediate between general emotional distress and overall tinnitus distress.

Model 2 differed from model 1 only in that the path between emotional distress (measured by the CORE-OM) and attention and monitoring (measured by the TVAQ) was omitted. This is because there is no reliable evidence that emotional distress influences tinnitus distress by means of increasing attention and/ or monitoring. All other assumptions are the same and the two IPQ-M subscales (symptom control and treatment control) remain the exogenous variables.

Model 3 differed from model 2 in that the beliefs construct has been omitted altogether. The exogenous variables are positive and negative thoughts, measured by the two subscales of the Tinnitus Cognitions Questionnaire (TCQ F1 and TCQ F2.) Models 1-3 are illustrated in figure 2.

\*\*Insert figure 2 here\*\*

Figure 2: model 1, with dotted lines showing elements that were omitted to create models 2 and 3. TRQ=tinnitus reaction questionnaire, CORE=clinical outcomes in routine evaluation, TCQ=tinnitus cognitions questionnaire, TFAS= tinnitus fear avoidance scale, TMI= tinnitus magnitude index, TVAQ= tinnitus vigilance and awareness questionnaire, IPQ= illness perception questionnaire, F=factor.

Model 4 had magnitude (measured by the TMI) as the exogenous variable and a path between avoidance behaviour (measured by the TFAS) and beliefs (measured by the IPQ-M) for consistency with the original model, which proposes that behaviour influences beliefs. This path was omitted from models 1-3 in order to maintain the IPQ-M’s status as an exogenous variable. Model 4 is illustrated in figure 3.

\*\*insert figure 3 here\*\*

Figure 3: model 4

An alternative version of the model omitted the path between IPQ-M and TFAS (control beliefs and behaviour) as the relationship between beliefs and behaviour has been little investigated in tinnitus research. In Model 5 (figure 4) the path between the IPQ-M (used to measure beliefs) and the TFAS-M (used to measure avoidance behaviour) was removed. A consequence of this is that both factors of the IPQ-M become exogenous variables along with the TMI (which measures magnitude).

In Model 6 (figure 4) the IPQ-M was omitted altogether. Without the IPQ-M there is only one exogenous variable; the TMI. A summary of the key features of each model is given in table 1.

\*\*insert figure 4 here\*\*

Figure 4: model 5, with dotted lines showing elements omitted to create model 6.

## Results

Of the 534 people who initially expressed interest in participating, 438 (82%) went on to fill in a consent form. Of these, 342 (78%) went on to complete the full survey. The large majority of these completed the survey online (323 = 95%.) The remaining 19 participants (5%) completed the survey on paper and returned it in the post. For a discussion of the merits and disadvantages of online data collection in this study, please see Handscomb et al. (2016). Progress of participants through the study is illustrated in figure 5.

\*\*insert figure 5 here

Figure 5: flowchart showing participants’ progress through the study.

There were 186 male and 156 female respondents. Thirty-five participants (10%) rated their tinnitus as ‘not a problem’, 85 (25%) rated it as ‘a small problem’, 102 (30%) rated it as ‘a moderate problem’, 83 (24%) rated it as ‘a big problem’ and 37 (11%) rated it as ‘a very big problem.’ Mean age, tinnitus duration and scores for each of the questionnaires in the survey are shown in table 2. Although anyone who had experienced tinnitus for more than 2 months was eligible, all but seven of the participants reported having tinnitus for a year or more, and only three participants reported having it for less than six months. Therefore the results should be taken to reflect the experiences of people with chronic not acute tinnitus.

\*\*insert table 2 here\*\*

#### Results of model testing

A comparison of fit indices for all models is shown in table 3. Those meeting the criteria for an acceptable fit are shown in bold.

\*\*insert table 3 here\*\*

The differences in fit indices between all models tested were small, and structural models which were conceptually close to and further away from the theoretical model were equally well supported by the data. Statistics for model 3 just exceeded the values required for an acceptable fit, therefore this model was rejected. Models 1, 2, 4, 5 and 6 all reached acceptable fit criteria. Model 2 is a slightly better fit than Model 1 and is more parsimonious as there is no path between CORE-OM (emotional distress) and TVAQ (attention). There are no empirical grounds for maintaining this path even though it appears in the original theoretical model. Model 5 is a slightly better fit than Model 4, and again there are no empirical grounds for maintaining the path between behaviour and control beliefs, therefore the more complex Model 4 was also excluded from further analysis. Model 6 (with the IPQ-M, measuring control beliefs, excluded and the TMI, measuring magnitude, as the exogenous variable) was a somewhat better fit than Model 5, which has two exogenous variables (TMI and IPQ-M) Nevertheless, the differences in fit statistics were not large enough to provide a clear case for excluding a variable.

The modification indices for models 2, 5 and 6 were examined. Any modifications which involved simply reversing the direction of a path between one variable and another were not considered for testing. Modifications which involved changing the status of either the exogenous or the outcome variable were also rejected. For all models, the only modifications that were theoretically plausible were the addition of a path from CORE F1 (negative emotions) to TFAS F1 (tinnitus-related avoidance) and the addition of a path from TMI (perceived magnitude) to TFAS F1 (tinnitus-related avoidance). Although these connections have not been investigated in tinnitus, it is plausible that a negative emotional state increases the likelihood of avoiding certain situations and that louder tinnitus also leads to avoidance; particularly as some of the situations to be avoided involve noise exposure, and people may worry about noise making their tinnitus even louder (Erlandsson, 2008). The models were re-tested with the addition of a path from CORE F1 to TFAS F1 first (creating new models 2.1, 5.1 and 6.1) and then with the addition of both this path and another from TMI to TFAS F1 (creating new models 2.2, 5.2 and 6.2).

Addition of the new parameters slightly improved the fit of all the models tested. As the models which included both modifications fit better than those which included only one, these (models 2.2, 5.2 and 6.2) were retained for further examination. Fit indices for models including modifications are shown in table 4. Standardized parameter estimates (with standard errors) for all three finally retained models are shown in supplementary tables 1, 2 and 3.

\*\*insert table 4 here\*\*

Comparing model 5.2 with model 6.2, the lack of any significant regression path between control beliefs and negative thoughts (TCQ) calls into question the role of control beliefs in this configuration of the model. Given that the data fit Model 6.2 (from which IPQ-M, measuring control beliefs, is omitted) somewhat better than Model 5.2, Model 5.2 was rejected.

The two retained models, showing all standardised estimates, are illustrated in figures 6A and 6B. Statistically significant standardized parameter estimates indicate a relationship between a predictor variable and an outcome variable, with higher values indicating a stronger predictive relationship. Full parameter estimates are given in supplementary materials 1 and 2 and parameters of other models can be obtained through contact with the corresponding author.

\*\*insert figure 6A here\*\*

Figure 6A: SEM configuration of the cognitive behavioural model of tinnitus distress with control beliefs as the exogenous variable (Model 2.2). Statistically significant paths are marked with \*.

\*\*insert figure 6B here\*\*

Figure 6B: SEM configuration of the cognitive behavioural model of tinnitus distress with tinnitus magnitude as the exogenous variable (Model 6.2). Statistically significant paths are marked with \*.

## Discussion

In this study, we tested several configurations of a Cognitive Behavioural Model of Tinnitus Distress. In both retained models, the comparative fit indices (CFI and TLI) indicate a good fit compared to a null model, and in both the RMSEA indicates an acceptable fit compared to a perfect model, which approaches the threshold for a good fit. While the fit of Model 6.2 is slightly better across all indices than that of Model 2.2, the differences are not large enough to favour Model 6.2 on statistical grounds, therefore theoretical arguments need to be considered.

Model 2.2 makes the assumption that the amount of attention directed towards tinnitus largely determines how loud and severe tinnitus is perceived to be. It also sees the process of tinnitus distress as being ‘driven’ by beliefs about control. On the other hand, model 6.2 sees perceived magnitude to be the ‘driver’ of ensuing psychological processes, including attention, and control beliefs are omitted. Model 2.2 is more similar to the original Cognitive Behavioural Model of Tinnitus Distress proposed by McKenna et al. (2014). It reflects one of the core principles of CBT; that beliefs are deep- rooted and give rise to thoughts and emotions, which are more transient. Bearing these principles in mind, beliefs seem to be a logical starting point. Going against this idea however is the fact that the type of control beliefs measured in this study appeared to be only very weakly related to tinnitus distress. The fit indices for Model 2.2 are not a great deal worse when beliefs are excluded and are better for Model 6.2. It would be interesting to investigate whether a ‘beliefs- driven’ model would fit better if a different type of belief were measured using a different instrument. Some participants who rated their tinnitus as ‘not a problem’ or ‘a small problem’ had low scores on the IPQ-M and did not even partially agree with statements such as “there is a lot which I can do to control my tinnitus.” This suggests that there may be people who do not believe they can control their tinnitus but for whom this does not matter. An earlier study of a clinical population ([Handscomb, 2006](#_ENREF_76)) reached a similar conclusion. Many patients answered Yes to the question “Do you feel that you have no control of your tinnitus?” while answering No to most other items on the Tinnitus Handicap Inventory, suggesting that it is possible to feel you have no control over tinnitus without feeling angry, irritated, or depressed. Perhaps a more pertinent question to ask, rather than “do you feel you can control your tinnitus” is “does feeling in control matter to you?”. Work by [Andersson et al. (2005a](#_ENREF_3)) has indicated that certain dimensions of perfectionism are related to tinnitus distress and the authors suggest this may be because the uncontrollability of tinnitus may be particularly unsettling for people to whom neatness and order are very important.

Although the phenomenon of distorted perception could not be tested directly in any structural model, Model 2.2 does include the supposition contained within it; that perceived loudness is chiefly a product of attention. Existing studies which show a lack of correlation between matched and self-rated loudness (for example, De Ridder, Congedo, & Vanneste, 2015) lend some support to the idea that perceived loudness may be influenced by psychological processes. In the survey, 97% of participants in the ‘big problem’ and ‘very big problem’ categories gave their tinnitus a loudness rating of 5 or more, with 29% of participants in these two groups giving it the highest possible rating of 10 out of 10. Sixty three percent of participants in the ‘not a problem’ group gave their tinnitus a loudness rating of less than 5. However, there were a small number of people who categorised their tinnitus as ‘not a problem’ who also rated it as loud. Thirteen out of the thirty-five people in the ‘not a problem’ group gave their tinnitus a loudness rating of more than 5 out of 10, and of these, one gave it a 7 and one a 10. Similar findings were reported by Hiller & Goebel (2007). There is an indication here that there is a (fairly small) subgroup of people who are not troubled by loud tinnitus, which perhaps lends some support to the idea that tinnitus loudness may be influenced by external factors. Clinically, patients often describe loudness increasing with worse hearing, blocked ears or infections, or simply a change in their environmental surroundings.

If loudness perception could be influenced by psychological therapy, this would indicate that psychological processes influence it to at least some degree. A number of studies (some of which are reviewed by Martinez-Devesa et al. 2010) have found that loudness perception stays the same even when distress decreases, which supports the idea that loudness is to some degree external to the tinnitus distress cycle. A recent exception, however, is an investigation of mindfulness-based CBT by McKenna et al. (2017). In that study, patients who benefitted from mindfulness reported significant reductions in their loudness ratings, indicating that breaking the cycle of negative thoughts, emotional distress and selective attention may result in the perception of tinnitus being less distorted.

Given their statistical similarity and the theoretical arguments in favour of both, there are no grounds for regarding one model as superior to the other. Rather, different people with tinnitus may see their experience reflected more in one model or the other. It has often been proposed in tinnitus literature that tinnitus should not be regarded as a unitary condition (Hall et al, 2015; Van de Heyning et al. 2015) and a number of proposals have been made for identifying tinnitus sub-types (Landgrebe et al. 2010; van den Berge et al. 2017). There may well be a sub-group of people with tinnitus for whom loudness perception is largely influenced by physiological factors such as hearing damage or sinus problems, and another for whom loudness perception is influenced more by selective attention and monitoring. Patients who find themselves ‘checking up’ on their tinnitus as they move into different environments or switch activities would fall into this latter category. For some patients, a relatively low-intensity tinnitus signal may become salient because of the thoughts surrounding it, while for others tinnitus perhaps needs to be high in intensity before attention is directed towards it. Latent class analysis of a large group of participants would help to establish this. Essential additions to this investigation of possible subtypes would be to test whether the association between loudness and distress is stronger for certain groups than others, and to ask people with tinnitus specifically about their views on tinnitus loudness- do they see the loudness of their tinnitus as something which ‘just is’, or do they feel it is strongly influenced by attention? It would be interesting to show people with tinnitus the two best fitting versions of the model and ask them to comment on which they feel is more applicable to them. Of course, the two possibilities are not mutually exclusive; it may be that increasing deafness triggers louder tinnitus and by paying attention to that louder tinnitus the person perceives it as louder still. Nevertheless, being able to distinguish different ‘loudness perception’ subgroups could be helpful in planning therapy, with more emphasis on reducing monitoring behaviour, for example, for people whose loudness perception is largely driven by attention and perhaps more emphasis on sound therapy and amplification when there is a strong association between loudness and distress.

Examination of the parameter estimates for both models indicates that certain measured variables have particularly strong relationships with one another, while other relationships are weak, even when they reach statistical significance. For example, in model 2.2 there is a strong relationship between TCQF1 (negative thinking) and all four factors of the TVAQ (attention). Similarly, the relationship between preoccupation with tinnitus and tinnitus magnitude is strong, but the other three factors of the TVAQ (awareness of changes, monitoring and ability to ignore) are only weakly related to tinnitus magnitude (in the case of ability to ignore, the relationship is not statistically significant). While there have been several laboratory studies of tinnitus and attention (for example, Mohamad, Hoare, & Hall, 2016) there has been little investigation of day to day attention. A more in-depth investigation of the different types of vigilance and awareness indicated on the TVAQ might be helpful in establishing which are more strongly associated with tinnitus magnitude and tinnitus-related distress and indicate appropriate targets for therapy.

Limitations associated with the survey method of data collection applied to this project. A survey answered at a single time point can only ever be a ‘snapshot’ of a person’s situation and, with a condition that fluctuates like tinnitus, this means it may not reflect how things are most of the time.

It is good practice to cross-validate models using different data. Unfortunately, no existing studies have investigated even a section of the models tested in this project using the same questionnaires or near equivalents. In the future, it would also be valuable to re-test the models using different samples, perhaps in particular a clinical sample, to see whether one configuration fits a group of help-seekers better than the other. Testing the models in populations outside the UK would also help to establish how cross-cultural the findings of this project are.

Finally, this model cannot be regarded as an exhaustive explanation of tinnitus-related distress. There are many other potential contributing factors (including hearing difficulty, sleep disturbance, specific mental disorders and personality traits) which were not assessed here. Any model that can feasibly be tested using these statistical methods can only be a partial explanation of the multi-faceted phenomenon of tinnitus-related distress.

## Conclusion

This study has been the first to provide robust, empirical support for any model of tinnitus distress. While no definitive conclusion can be drawn as to the most appropriate configuration of the model, the relevance of all components of the original, theoretical Cognitive Behavioural Model to tinnitus distress- with the possible exception of beliefs- has been established, and their inter-relatedness has been confirmed. This is important, as it indicates that targeting one is also likely to have an effect on others. If, for example, learning mindfulness reduces negative thinking, this in turn is likely to reduce the amount of attention paid towards tinnitus. A negative cycle of thoughts, behaviour and attention may be broken by addressing any one of these components, and which to address first should be decided through careful discussion with the patient.

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## Figure legends

Figure 1: Cognitive Behavioural Model of Tinnitus Distress; reproduced from (Laurence McKenna et al.. 2014)

Figure 2: model 1, with dotted lines showing elements that were omitted to create models 2 and 3. TRQ=tinnitus reaction questionnaire, CORE=clinical outcomes in routine evaluation, TCQ=tinnitus cognitions questionnaire, TFAS= tinnitus fear avoidance scale, TMI= tinnitus magnitude index, TVAQ= tinnitus vigilance and awareness questionnaire, IPQ= illness perception questionnaire, F=factor.

Figure 3: model 4

Figure 4: model 5, with dotted lines showing elements omitted to create model 6.

Figure 5: flowchart showing progress through the study

Figure 6A: SEM configuration of the cognitive behavioural model of tinnitus distress with control beliefs as the exogenous variable (Model 2.2). Statistically significant paths are marked with \*.

Figure 6B: SEM configuration of the cognitive behavioural model of tinnitus distress with tinnitus magnitude as the exogenous variable (Model 6.2). Statistically significant paths are marked with \*.