

Review

A systematic review and meta-analysis of psychological functioning in chronic tinnitus

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HIGHLIGHTS

- A comprehensive review of psychological functioning in chronic tinnitus (CT)
- Reduced cognitive functioning is primarily associated with the presence of CT.
- Reduced emotional wellbeing is associated with an increased impact of CT.
- A broad array of psychological functions is involved in this pervasive condition.
- Possible psychological mechanisms maintaining CT are discussed.

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ABSTRACT

Chronic tinnitus, the phenomenon of a chronic ringing in the ears or head, has a significant negative impact on an individual's health and wellbeing. Despite this, there is no cure or consensus regarding factors maintaining ongoing awareness of the sensation in this population, or the severity of its impact. We aimed to comprehensively and systematically review behavioural studies investigating the psychological functioning of adults with chronic tinnitus. We identified 64 papers meeting our search criteria for inclusion, which are reviewed with regard to psychological factors involved with the presence of chronic tinnitus, and those relating to its severity. The majority of studies assessed the presence and impact of chronic tinnitus with regard to emotional wellbeing ($n = 59$), with a more recent interest in cognitive functioning ($n = 16$). A subset of 36 studies was included in meta-analyses investigating the relationships between emotional wellbeing and the presence and impact of chronic tinnitus using random-effects models. Our findings indicate the presence of chronic tinnitus may be associated with reduced cognitive functioning, particularly attention, and with reduced emotional wellbeing, particularly anxiety and depression. We also found consistent evidence indicating severity of chronic tinnitus is associated with a broad range of psychological features, primarily symptoms of depression and anxiety. We recommend investigating the complexity of the relationships between emotional wellbeing, cognitive functioning, and chronic tinnitus using a range of methodologies to further elucidate the role of psychological functioning in chronic tinnitus.

1. Introduction

The experience of tinnitus, also known as a phantom auditory perception, is often described as a ringing, buzzing or hissing sound in the ears or head. It is a subjectively reported condition with no diagnostic tests available, nor an established treatment protocol despite its substantial economic burden (Maes, Cima, Vlaeyen, Anteunis, & Joore, 2013). In its chronic form, typically defined as > 3 months duration, tinnitus is a complex sensory and psychological experience with high variability in the spectrum of experiences between people (Hoffman & Reed, 2004). Furthermore, chronic tinnitus (CT) is often associated with

reduced quality of life and psychosocial wellbeing (Tyler & Baker, 1983). The prevalence of CT varies according to the definition used in population based studies, however estimates typically suggest 10–15% of the general population experience CT (Henry, Dennis, & Schechter, 2005).

Mechanisms of CT are generally conceived with regard to three distinct disciplines: audiology, neurobiology, and psychology. Dysfunction of the ear, hearing abilities, and auditory pathway functioning remain dominant themes in both clinical practice and research, particularly regarding the mechanisms of the onset or generation of the tinnitus sensation (Eggermont & Roberts, 2004; Jastreboff, Gray, &

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Gold, 1996). Advances in neuroimaging have highlighted neuroplasticity of both auditory and non-auditory brain regions in CT, particularly emotion, attention and memory regions, thus cementing the interest of neuroscientists in this condition (De Ridder, Elgoyhen, Romo, & Langguth, 2011; Husain, 2016; Rauschecker, Leaver, & Mühlaus, 2010). In addition to neurobiological evidence suggesting a role of psychological functions, patients often describe a significant negative impact of CT on daily life. This has fuelled a growing interest in the contribution of psychological functioning to the experience of CT beyond a comorbidity or symptom of ongoing awareness of the sensation, but as a potential contributor to the ongoing awareness, loudness and severity of the tinnitus sensation (McKenna, Handscomb, Hoare, & Hall, 2014; Rauschecker et al., 2010; Searchfield, 2012). Recent reviews have addressed aspects of auditory and neurobiological functioning in chronic tinnitus (e.g., Eggermont & Roberts, 2015; Elgoyhen, Langguth, De Ridder, & Vanneste, 2015; Husain, 2016; Roberts, Husain, & Eggermont, 2013; Shore, Roberts, & Langguth, 2016), thus a comprehensive review of the role of psychological functioning in this population is now required.

Psychological processes as contributors to the ongoing awareness and severity of tinnitus are typically conceptualised as part of a 'vicious cycle' in models of CT (De Ridder et al., 2011; Jastreboff et al., 1996; McKenna et al., 2014). While most people habituate the tinnitus sensation, in these models the tinnitus sensation may become associated with anxiety and other negative psychological processes (e.g., catastrophising thoughts, poor attention control). This, in turn, may sensitise an individual to continue directing cognitive and emotional resources to the tinnitus sound, thus preventing habituation to the sensation. This may subsequently further enhance negative associations and severity, compounding the failure to habituate to the sound and increasing the severity of its impact (Jastreboff et al., 1996). As such, a wealth of new studies has focused on emotional wellbeing and cognitive factors that may account for the overarching failure to habituate to the sensation (i.e., tinnitus presence), and/or the spectrum of severity of the impact of tinnitus on daily life (i.e., tinnitus severity) in people with CT (see Fig. 1).

1.1. Generation vs. maintenance of chronic tinnitus

In considering the variety of proposed mechanisms underpinning CT across audiological, neurological and psychological fields, a distinction emerges between concepts principally dealing with generation of the tinnitus sensation and mechanisms focused on ongoing awareness or 'maintenance' of the sensation. Mechanisms relating to the initial generation of the tinnitus sensation have been dominated by auditory research in both human and animal studies, particularly around causal mechanisms at the level of peripheral and central auditory pathways facilitating aberrant auditory activity (Eggermont & Roberts, 2004). Of note, some of these models also consider ongoing awareness of the sensation, primarily drawing on non-auditory or psychological processes for this aspect of CT perception. For example the Neurophysiological Model of Tinnitus separates generation mechanisms relating to the discordant damage hypothesis of inner/outer hair cell dysfunction, from ongoing awareness of the sensation via the 'vicious cycle' involving limbic and autonomic nervous system structures for maintained awareness, hypervigilance and emotional distress (Jastreboff et al., 1996). In light of this, there is growing evidence that while generation of the sensation is reflected in central auditory pathways following peripheral auditory disruption, maintenance mechanisms may be underpinned by emotion and cognitive processes (Adjajian, Sereda, & Hall, 2009; Husain, 2016).

As a result, the need to consider how the perception of the tinnitus sensation becomes a chronic condition has become a core focus of recent research regarding the mechanisms underpinning CT (Georgiewa, Klapp, Fischer, Reissbaur, Juckel, Frommer, and Mazurek, 2006; Guillon, 2012; Jastreboff & Hazell, 1993). In particular, while auditory

system dysfunction, both peripheral and central remains a predominant causal mechanism for generation of the tinnitus sound, the ongoing involvement of emotion, attention and memory functions has been implicated in facilitating conscious awareness of the sound (presence) and the severity of its impact (De Ridder et al., 2011; De Ridder, Vanneste, Weisz, Londero, Schlee, Elgoyhen, and Langguth, 2014; Husain, 2016).

1.2. Purpose and scope of review

We aimed to comprehensively and systematically integrate current literature investigating the psychological functioning of adults with CT, primarily behavioural cross-sectional studies. In addition, we aimed to use meta-analytic techniques where appropriate to assess the contribution of psychological functioning to the experience of CT. To achieve this, we identified and analysed peer-reviewed behavioural and observational research studies in the field of CT that aimed to capture the experience of CT with regard to factors maintaining awareness of the sensation in this chronic population (i.e. presence) and factors contributing to the severity of its impact (severity). We used the PRISMA statement to guide our review strategy (Moher, Liberati, Tetzlaff, Altman, The PRISMA Group, 2009). We hypothesised that (1) impaired psychological functioning, specifically reduced emotional wellbeing and reduced cognitive functioning, would be observed in people with CT compared to people without CT, reflecting a role of psychological functioning in maintaining awareness of the tinnitus sensation, and (2) that impaired psychological functioning would be associated with greater severity of the impact of the tinnitus sensation on day-to-day life in this population.

2. Methods

2.1. Identification of studies

We searched for studies describing the psychological functioning of adults (≥ 18 years) with CT. Typically CT is defined as the subjective experience of a constant ringing in the ears or head for > 3 months, although some studies report accepted cut-offs for CT of 1 month (e.g., (Meric, Gartner, & Collet, 1998) or 6 months (e.g., (Crocetti, Forti, Ambrosetti, & Bo, 2009)). For inclusiveness, we adopted the 1-month cut-off for tinnitus to be considered chronic. Our search was limited to available peer-reviewed, full-text journal articles written in English that directly addressed the psychological functioning of people with CT. To identify studies in this area, we searched the PsycInfo and Medline databases using four search strategies: (1) tinnitus AND psych* (all fields), (2) tinnitus AND mood (all fields), (3) tinnitus AND depress* (all fields), and (4) tinnitus AND anx* OR stress (all fields). PsycInfo was chosen as a comprehensive international database for psychological research in a broad sense, while Medline was chosen as a large international database for medical and health care related research including relevant fields of audiology, psychiatry and allied health. The first search term was chosen for topic breadth, while the remaining search terms were based on key terms commonly used in psychological research in CT to try and capture studies addressing topics relevant to the present review. We also searched the reference lists of articles reaching the data extraction stage of the systematic review using the same screening criteria applied to articles identified in the original search.

2.1.1. Article selection and data extraction

All available studies identified using the above search strategies and published prior to 27 November 2015 were included in the initial title screen ($n = 725$). First, we identified and removed duplicates ($n = 338$), leaving 387 articles for further review (Fig. 2). During title and abstract screening we excluded case reports ($n = 15$), animal studies ($n = 1$), and articles about the following: (i) children and

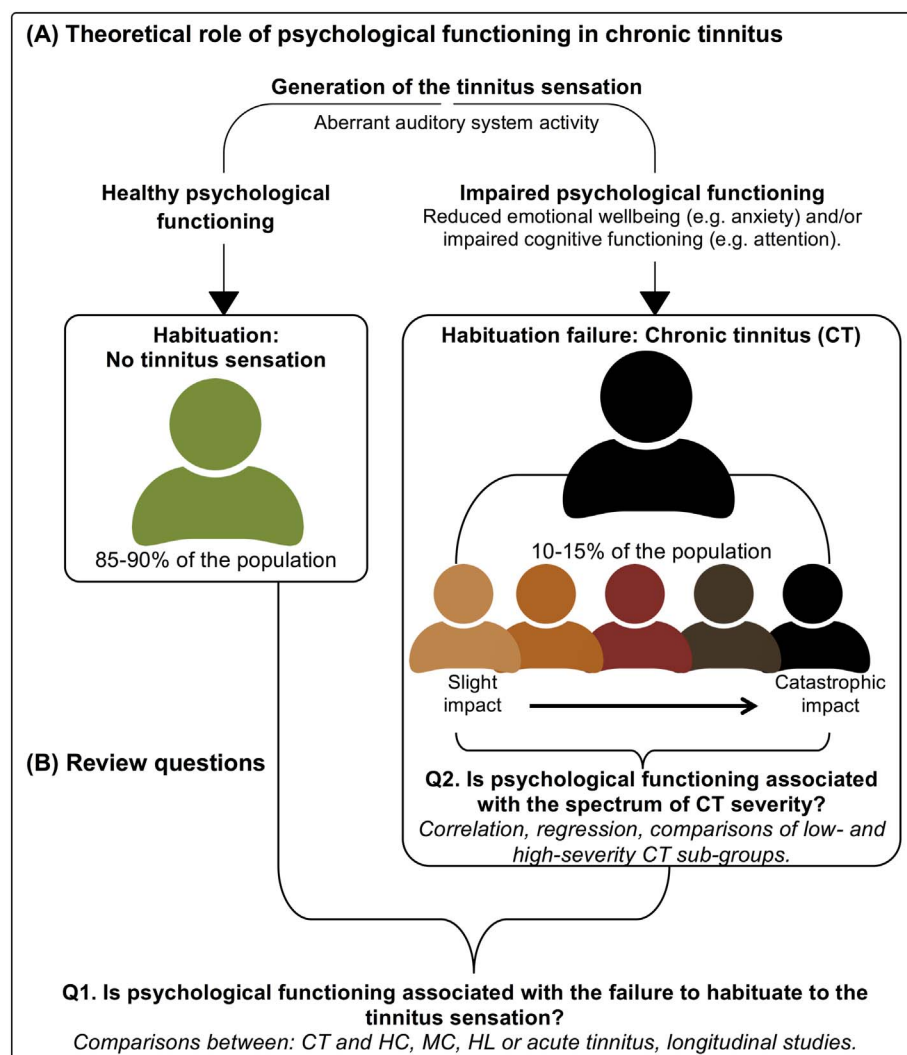


Fig. 1. Proposed contribution of impaired psychological functioning to chronic awareness of tinnitus (i.e. presence) and the spectrum of tinnitus severity (panel A). The two core questions arising from this proposal for review are outlined in panel B. Possible techniques for investigating these questions are noted in italicized font under each review question. CT = chronic tinnitus, HC = healthy control, MC = medical control, HL = hearing loss control.

adolescents (i.e., ≤ 18 years; $n = 1$), (ii) acute tinnitus (< 1 month; $n = 3$), (iii) other clinical populations (primarily Meniere's disease and traumatic brain injury; $n = 105$), (iv) treatments or treatment factors ($n = 34$; for reviews see [Andersson, 2002](#); [Dobie, 1999](#); [Hoare, Stacey, & Hall, 2010](#)), (v) measurement development and/or psychometric properties of tinnitus measures ($n = 11$), and (vi) articles which did not primarily address psychological functioning ($n = 129$). Articles rejected based on criteria (vi) were primarily investigations of neurobiological factors such as electroencephalography, endocrinology, and transcranial magnetic stimulation (recently reviewed by [Peng, Chen, & Gong, 2012](#); [Theodoroff & Folmer, 2013](#)), and neuroimaging studies (recently reviewed by [Adjamian, Hall, Palmer, Allan, & Langers, 2014](#); [Eggermont & Roberts, 2004](#); [Husain, 2016](#); [Roberts, Husain, and Eggermont, 2013](#)). Eighty-seven articles reached full-text review of which we excluded review articles without original data, and articles that subsequently met the above exclusion criteria (points i-vi).

We also required studies to report details of the impact of tinnitus on participants using an established measure (e.g., Tinnitus Handicap Inventory (THI), Tinnitus Reaction Questionnaire (TRQ), Tinnitus Questionnaire (TQ)) to enable quantification of the impact of CT. Including a gold-standard, psychometrically robust measure quantifying the tinnitus experience helps participants to reflect on the chronic nature of tinnitus and aids in verifying that participants in the sample are experiencing a chronic sensation through its disruption (minimal or severe) on daily life. However, for inclusivity, we revised this criterion to include studies using visual analogue scales ($n = 3$) or a series of 6–9

questions ($n = 3$) aiming to assess impact on daily life (e.g. interfering with sleep, relationships, and concentration).

When measuring the severity of the impact of tinnitus on day-to-day life, it is important to note that there is minor overlap or 'redundancy' in some questions on tinnitus severity measures with questionnaires assessing specific emotional wellbeing factors. As a result the potential for observed correlations to represent methodological artefact has been a source of debate within the field ([Hébert, Canlon, Hasson, Magnusson Hanson, Westerlund, and Theorell, 2012](#); [Ooms, Meganck, Vanheule, et al., 2011a](#); [Ooms, Meganck, Vanheule, et al., 2011b](#)). While tinnitus severity scales have been validated with regard to other measure of emotional wellbeing, this has been to establish divergent construct validity, rather than convergent construct validity ([Cronbach & Meehl, 1955](#)). For example in validating the THI, a small correlation with the BDI ($r = 0.32$) was observed, indicating divergent validity with some minor overlap as expected between the construct of depression and the construct of impaired day-to-day functioning resulting from tinnitus. In contrast a large correlation was observed with another tinnitus severity measure ($r = 0.78$) demonstrating convergent validity, indicating both measures assessed the same construct ([Newman, Jacobson, & Spitzer, 1996](#)).

In this context, while a tinnitus severity tool may ask questions to assess the emotional, cognitive or general impact of tinnitus, these questions are specifically assessed as a consequence of the tinnitus sensation such as "because of my tinnitus is it difficult for you to concentrate?" (THI; [Newman et al., 1996](#)) or "how anxious or worried has

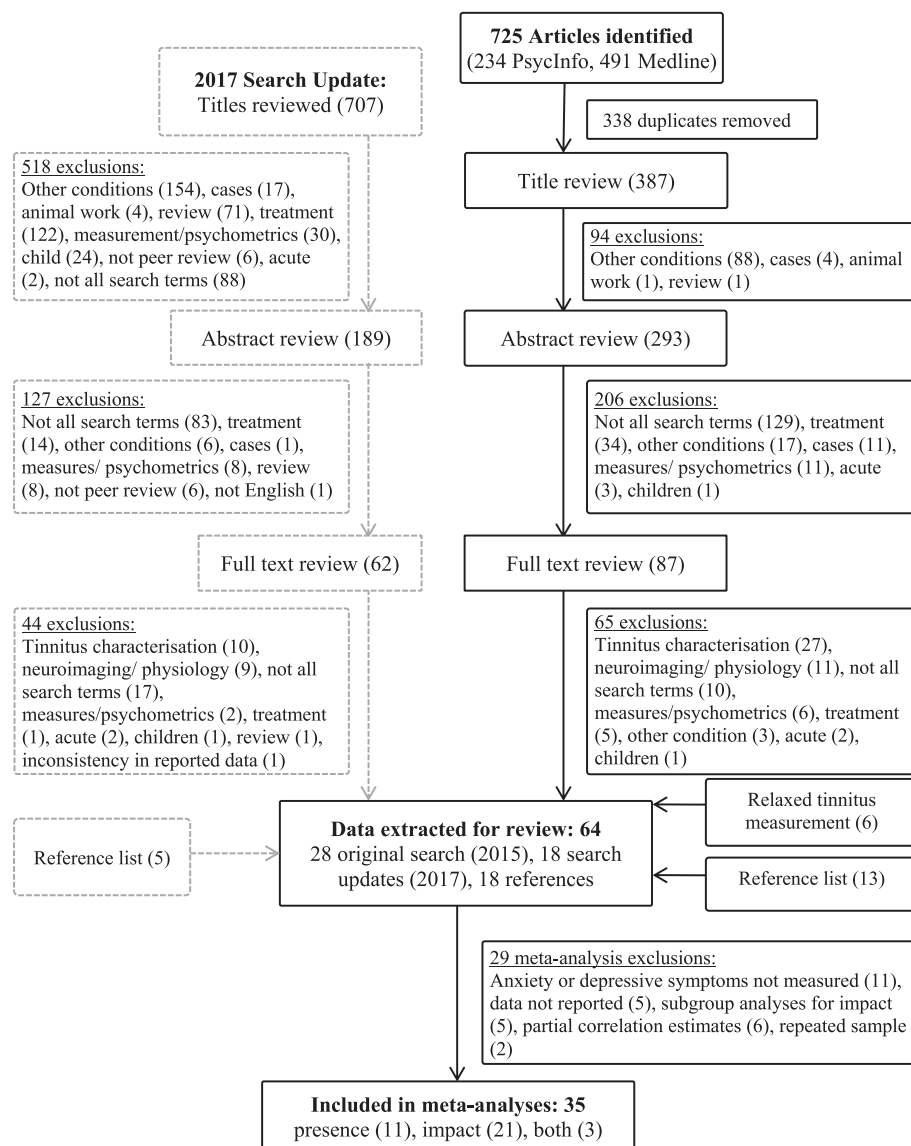


Fig. 2. Flow chart of the article review process. The original 2015 search is indicated by black boxes and arrows and the 2017 search is indicated by dashed gray boxes and arrows.

your tinnitus made you feel?” (TFI; Meikle, Henry, Griest, Stewart, Abrams, McArdle, et al., 2012). In contrast, a measure of psychological functioning such as cognitive difficulties (e.g. Cognitive Failures Questionnaire) or anxiety (e.g. State Trait Anxiety Inventory) typically have a series of questions to broadly assess these domains covering somatic, affective, functional symptoms across general day-to-day life (Hébert et al., 2012). While there is a small risk of redundancy, when moderate to large effect sizes are observed between these measures, it is reasonable to attribute the association to a true observation, rather than a methodological artefact.

We also assessed the quality of included articles, based on established guidelines and quality-assessment tools for cross-sectional research (Matcham, Ali, Hotopf, & Chalder, 2015; Thomas, Ciliska, Dobbins, & Micucci, 2004). Quality probes included: clarity of research question, recruitment strategies and inclusion/exclusion criteria; whether the psychological variable of interest was measured with a validated tool, characterisation of CT in terms of severity with psychometrically robust scale (as opposed to a visual analogue scale or in-house questions) and duration (duration since onset, and frequency of perception); power analyses or other sample size justifications; measurement of confounding factors, particularly hearing; and adjustment or control for identified confounds. Where no information was available regarding a quality probe studies were coded as not having satisfied

that quality probe.

2.2. Data synthesis

Following article selection, we extracted data from all eligible studies ($n = 28$) relating to participant demographics, tinnitus characteristics, psychological outcome measures used, and the main findings of the study. In addition, we extracted data from 13 articles identified in the reference lists of studies meeting inclusion criteria. To keep the review current throughout the analysis and peer review process, we used search updates to screen titles, abstracts and articles as per the original search strategy. As at the 17 October 2017, this strategy had identified an additional 18 studies, with a further 5 identified through reference lists. Combined, this process resulted in a total of 64 articles included in the current systematic review (Fig. 2).

We synthesised the findings of the selected studies in two ways. First, we performed a review of the literature to integrate and summarise key findings. The significance and level of symptom endorsement, psychiatric history, or diagnostic status (i.e., presence of absence of a co-morbid mental health condition) informed emotional wellbeing results. The interpretation of cognitive functioning results was informed by slower reaction times and/or impaired performance in people with CT, particularly significance levels and effect sizes. Two specific

psychological processes were frequently identified in this process, anxiety and depression, which we further investigated using meta-analytic techniques on a subset of studies reporting on these factors. To address the hypothesis of this review, that impaired psychological functioning contributes to ongoing awareness of the presence of chronic tinnitus and the spectrum of tinnitus severity, we framed two targeted research questions for the meta-analyses: (1) do people with CT endorse more symptoms of anxiety and depression than people without tinnitus, and (2) how strong is the association between the severity of CT and symptoms of anxiety and depression.

2.2.1. Meta-analytic approach

To answer our first question, we included studies reporting the means, standard deviations and number of participants for the psychological measures of anxiety and depression in people with CT and people without tinnitus i.e., healthy controls (HC). We then computed Cohen's *d*, the standardised mean difference between groups, as the effect size measure using 'R' software, version 2.3.2 GUI 1.66 Mavericks build (7060) for Mac OS X (Del Re, 2015; R Core Team, 2015). As we could not determine if the original data in each study were normally distributed we calculated Cohen's *d* using the pooled variance calculation to limit potential bias and used a random-effects meta-analytic model to allow for variability in population characteristics across included studies (Coe, 2002; Hunter & Schmidt, 2004). We also used the Anderson-Darling normality test to check for normality within the meta-analytic dataset, which revealed normal distributions for these analyses. We excluded studies from the primary review that (i) did not report on anxiety or depression, (ii) did not report data from which we could extract effect sizes, (iii) did not compare CT to HC groups. To address our second question, we included studies reporting an appropriate effect size measure, namely a correlation coefficient *r*, or a statistic from which we could calculate *r* (e.g., standardised beta values from a regression), between a measure of anxiety or depressive symptoms and tinnitus impact. Correlation coefficients (*r*) were transformed to the Fischer's *z* scale for calculating random-effect models, with results reported as *r*-values for interpretation (Borenstein, Hedges, Higgins, & Rothstein, 2009). In addition to exclusion criteria (i) and (ii) above, we also excluded correlations reported only in CT subgroups and studies reporting partial correlations.

For both questions, we used established methods to average the *r* and *d* values for studies that reported multiple associations between anxiety and tinnitus measures, or depression and tinnitus measures (Rosenthal & DiMatteo, 2001). To avoid duplication, data were not included if the tinnitus population had been reported on in an earlier article already in the analysis, as was the case for the work of *Wallhäusser-Franke, Brade, Balkenhol, D'Amelio, Seegmüller, and Delb (2012); Wallhäusser-Franke, Delb, Balkenhol, Hiller, and Hörmann (2014), we found no evidence to suggest overlap in the participants for the work of Andersson (1996), *Andersson and Vretblad (2000), *Andersson, Bakhsh, Johansson, Kald, and Carlbring (2005), *Andersson, Edsjo, Kald, and Westin (2009), *Andersson, Ingerholt, and Jansson (2003), *Andersson, Khakpoor, and Lyttkens (2002), and as such all eligible studies from this group were included. A study using compiled data across numerous studies as part of the Tinnitus Research Initiative database was excluded due to the likelihood of overlap with data from already included studies (*Zeman, Koller, Langguth, & Landgrebe, 2014). We used effect sizes for all meta-analyses as these reflect scale-free, standardised measures of the relationship between the variables of interest thus allowing comparison between studies. Studies included in the meta-analyses are marked with an asterisk in the reference list and the study summaries presented in Appendix A, Table A.1.

All meta-analyses were performed with the 'metafor' package in 'R' (Viechtbauer, 2010). All effect sizes were calculated from available data for *d* and retrieved from reported correlations for *r*-values, with the exception of *Stuerz, Lafenthaler, Pfaffenberger, Kopp, Gutweniger,

and Guenther (2009) where *r*-values were calculated from reported significance values (*p*). For all analyses we used a random-effects model employing the DerSimonian-Laird method for estimating between-study variance (Borenstein et al., 2009; Field & Gillett, 2010; Hunter & Schmidt, 2000; Rosenthal & DiMatteo, 2001; Viechtbauer, 2010). Where a random-effect model showed significant evidence of heterogeneity between studies (determined by the *Q* statistic), we calculated the estimated distribution of true effects to quantify the implications of this possible variation in terms of effect sizes. This calculation provides an estimate of the distribution of the population effect size, providing upper and lower effect size values between which 95% of true effects are likely to be observed (Borenstein et al., 2009). In addition, we examined potential publication biases with the fail-safe *N* statistic to estimate the number of non-identified studies with null effects necessary to reduce the observed significance to $\alpha = 0.05$, and a trim-and-fill analysis to provide an estimate of the number of missing studies and adjusted unbiased meta-analysis effect size (Borenstein et al., 2009; Field & Gillett, 2010).

3. Results

In total, our search strategy resulted in 64 peer-reviewed studies examining the psychological functioning of people with CT. These studies were published between 1989 and 2017, with 70% of studies being conducted in European countries (predominantly Sweden 20%, and Germany 13), followed by the United States of America (14%), Australia (6%), Asia 4% (Japan 2%, South Korea 2%) and Canada (2%; see Fig. 3). Of the selected studies, 19% addressed the role of psychological functioning in perpetuating awareness of the sensation (i.e., comparisons to non-tinnitus controls), 55% investigated the role of psychological functioning in the spectrum of tinnitus impact severity, 23% utilised both approaches to investigate psychological functioning in CT, and 3% of studies manipulated the intrusiveness of tinnitus (Fig. 4). As expected, two broad components of psychological functioning were found in this field: 92% of studies included an analysis relating to emotional wellbeing and, more recently, investigations of cognitive functioning featured in 25% of studies, a detailed summary of all studies is outlined in Appendix A, Table A.1. Studies addressing emotional wellbeing included investigations of psychopathology, quality of life, depression and anxiety, and were predominantly investigated with regard to the severity of CT. In contrast, the smaller body of work on cognitive functioning in CT has primarily investigated the role of cognition by comparing people with and without CT (Fig. 4).

3.1. Study characteristics

3.1.1. Participants

The majority of studies (70%) sampled participants solely from clinics (2% were veteran clinics) with a further 5% drawn from clinical, and community or support groups combined. Support groups accounted for a further 8% of studies with a further 5% drawn from support groups and community populations. Community only samples were rare, representing 3% of articles (8% not stated), with one study reporting data extracted from the Tinnitus Research Initiative database (*Zeman et al., 2014). To address the potential bias in the literature and present review due to the over-representation of clinical cohorts, the results of the present systematic review and meta-analyses will be interpreted in the context of population level studies and the broader tinnitus literature. Mean duration of tinnitus ranged from 22.3 months (*Mannarelli, Pauletti, Mancini, Fioretti, Greco, De Vincentiis, and Fattapposta, 2017) to 14.68 years (*Trevis, McLachlan, & Wilson, 2016b). The mean age for CT groups ranged from 30.3 years to 70.0 years old and where comparison groups were used (e.g. healthy controls (HC) or medical controls), ages ranged from 30.3 years to 68.4 years old.

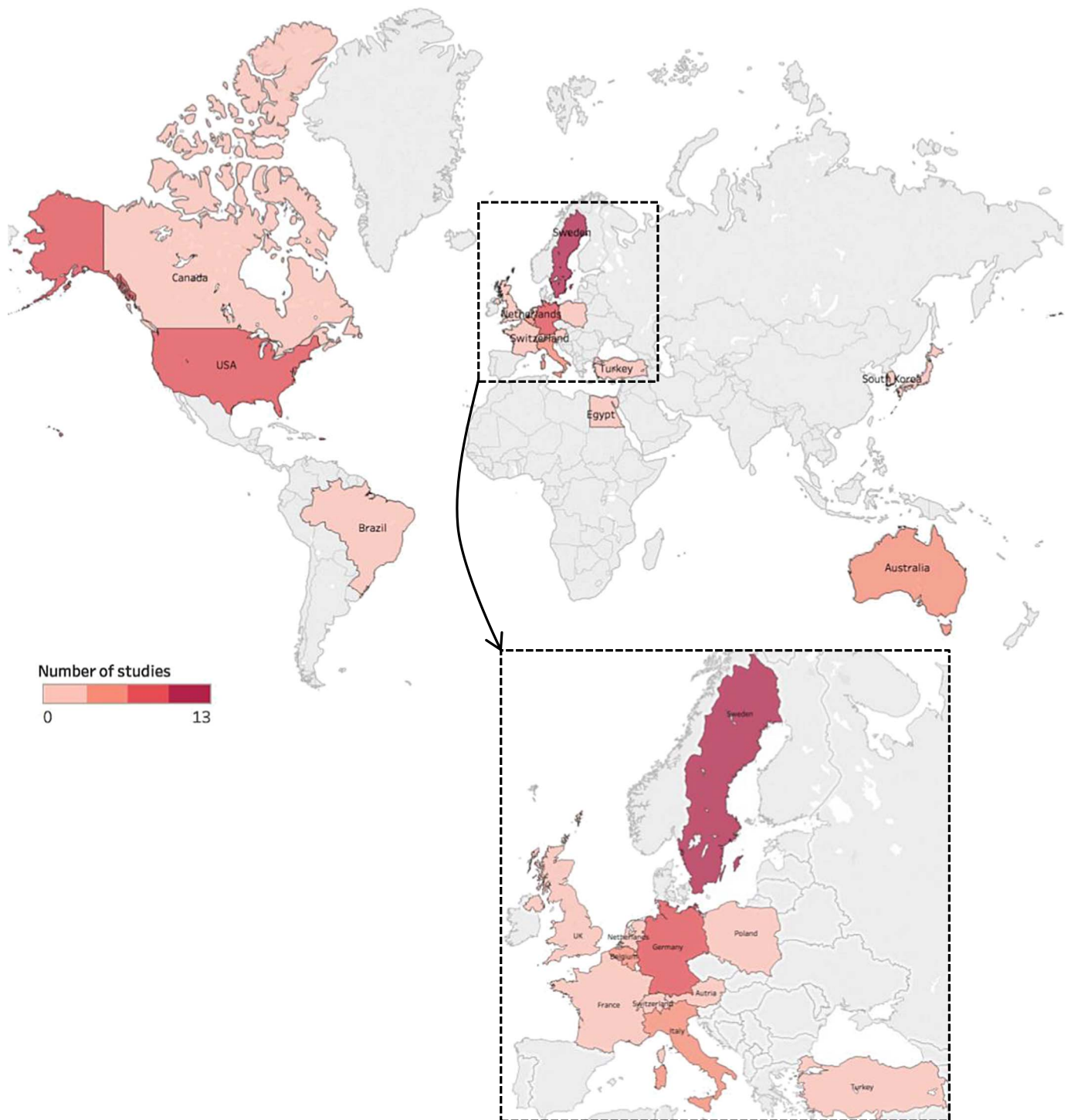


Fig. 3. Geographic distribution of studies included in this review. Majority of studies are based in European countries (see inset). Countries with darker shading indicate more articles originated there.

3.1.2. Quality assessment

Overall, the majority of studies were of good quality with the average quality score of 64% (19%). A summary of the quality assessment is presented in Table 1, which indicates that most studies provided a clear research question and identified their recruitment source. The majority of studies also reported the mean or median duration of tinnitus, and used a recommended psychometrically robust tool to assess tinnitus severity and psychological variables of interest, which likely reflects the inclusion criteria for the present review. We note a large proportion of full-text exclusions (35%) occurred due to a lack of

tinnitus quantification using an established measure with psychometric properties, or due to lack of evidence for *chronic* tinnitus (i.e. duration), which is important for evaluating the presence and severity of tinnitus beyond self-report of a phantom sound. Of note, only 16% of studies defined CT in terms of both duration (typically > 3 months) and how often individuals were aware of the sound (e.g. “most of the time”). Defining populations in future research will improve comparisons between studies that may contribute to frequently observed heterogeneity between studies of chronic tinnitus. We would encourage the inclusion of such a scale to provide this important information about how tinnitus

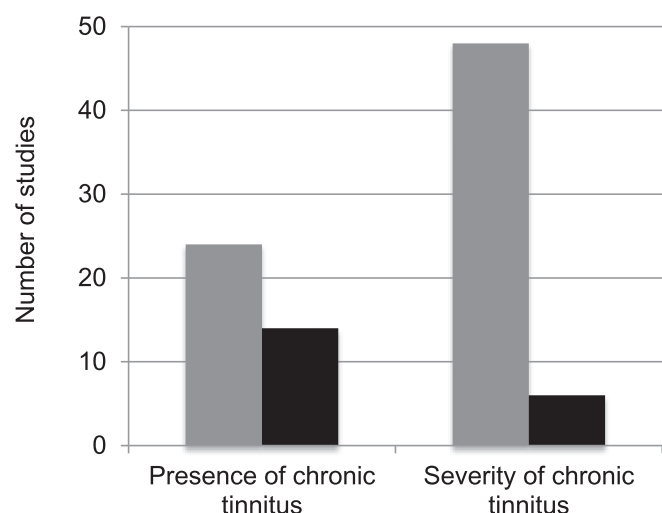


Fig. 4. Distribution of studies included in this review. Studies reporting emotional wellbeing information (gray bars) dominate this field compared to studies investigating cognitive functioning (black bars).

Table 1

Summary of quality assessment for studies investigating psychological functioning in chronic tinnitus included in this review ($n = 64$).

Quality probe	Probe present
Research question clearly stated?	92%
Study population clearly specified?	66%
Tinnitus diagnosis defined (time and frequency)?	16%
Recruitment source identified and consistent across groups where applicable?	95%
Duration of CT participants stated (beyond inclusion/exclusion criteria)?	83%
Tinnitus severity measured with a validated tool?	92%
Psychological variable(s) of interest measured using a validated tool?	98%
Power of the study or sample justification?	13%
Were potential confounds identified and measured (excluding hearing)?	81%
Was hearing measured?	59%
Were hearing and other confounds adjusted/controlled for?	59%

affects individuals in research and clinical practice as an indicator of the presence of the tinnitus sensation in day-to-day life, and the severity of its impact.

Power analyses (13%) and effect sizes were generally under-utilised in the studies included in this review, and we recommend their incorporation in future research as an element of standard practice. While most studies captured potential confounds relevant to their study design, typically demographic, psychosocial or related health and wellbeing factors, only 59% reported a measure of hearing health. Given the association between tinnitus and hearing loss, and the historic interest in hearing ability as a core factor relating to the presence of tinnitus, characterising hearing ability and adjusting or controlling for this can be beneficial. Of note, however, not all CT patients experiencing hearing loss, and not all patients with hearing loss experience tinnitus (chronic or intermittent). As such, hearing ability should not necessarily reduce the relevance of results generated by a well-designed and executed study.

3.1.3. Study designs

Three variations in study design were identified in this search: (1) studies investigating psychological functioning within CT populations (55%), (2) studies comparing subgroups of people with CT (30%), and (3) studies comparing individuals with CT to other control groups (44%). Of note, 6% of studies compared CT to medical controls with

chronic conditions, including other chronic medical conditions, hearing loss, or other ear, nose, and throat (ENT) conditions. These studies highlight the importance of considering the nature of the comparison group depending on the research question being investigated. In particular, the use of audiological, psychological and other medical control groups may provide information about unique psychological vulnerabilities in people with CT, as well as possible similarities to clinical populations where greater knowledge of mechanisms and treatments may already exist and thus inform potential mechanisms and treatments for CT. Comparisons with clinical control groups compliment studies using HC groups without tinnitus or other co-morbidities, by offering an additional (clinical) reference point, thus allowing further insight into the spectrum of difficulties people with CT may be experiencing.

3.2. Emotional wellbeing in people with chronic tinnitus ($n = 59$)

Fifty-nine studies investigating the emotional wellbeing of people with CT were identified in the present review. Measures of emotional wellbeing were frequently reported as part of characterising participants, in addition to studies specifically investigating this question. Thirty-seven percent of emotional wellbeing studies compared people with CT to HC groups or normative data, with four studies drawing comparisons to clinical control groups including ENT outpatients and people with hearing loss (Rutter & Stein, 1999), and people with other chronic health conditions (Zirke, Seydel, Szczepek, Olze, Haupt, and Mazurek, 2013; Kirsch, Blanchard, & Parnes, 1989). Fifty-eight percent of emotional wellbeing studies investigated the associations with tinnitus severity; in addition to nineteen studies (32%) performing subgroup analyses to address unpack this relationship.

Overall, examination of health-related quality of life (HRQoL) found reduction of HRQoL in the CT group compared to normative data with small to medium effect sizes. Reductions in quality of life were noted across the physical (e.g. pain, activities of daily living), social (e.g. relationships) and psychological (e.g. cognition, self-esteem, feelings) domains (Weidt, Delsignore, Meyer, Rufer, Peter, Drabe, and Kleinjung, 2016). Moreover, increased severity of tinnitus has been associated with decreased HRQoL (Zeman et al., 2014; Cima, Crombez, & Vlaeyen, 2011; Weidt et al., 2016). Decreased HRQoL observed here is consistent with the broader tinnitus literature, also demonstrating a link between the presence of CT and reduced quality of life (Erlandsson & Holgers, 2001; Tyler & Baker, 1983). In particular, population studies have shown a relationship between tinnitus and reduced HRQoL, including reduced HRQoL in people with hearing loss and tinnitus, compared to people with hearing loss who do not have tinnitus (Joo, Han, & Park, 2015; Nondahl, Cruickshanks, Dalton, Klein, Klein, Schubert, et al., 2007). By investigating more specific aspects of emotional wellbeing with regard to the presence of CT (Section 3.2.1.) and the severity of its impact (Section 3.2.2), the work summarised below provides targeted insights into the broad array of psychological functions linked to chronic tinnitus.

3.2.1. Is emotional wellbeing associated with ongoing awareness of chronic tinnitus?

In general, two core themes have been investigated within the context of the presence of CT: anxiety ($n = 16$) and depression ($n = 18$). Overall, 64% of studies investigating depression found an increase in depressive symptoms in people with CT compared to HC and 62% of studies investigating anxiety reported significantly increased anxiety symptoms in people with CT compared to HC. While other psychological functions have also been investigated, there is comparatively limited replication of these effects compared to the above research areas (summarised in Table 2).

A fairly consistent finding was that of increased depressive symptoms in people with CT compared to HC groups (e.g., Andersson et al., 2003; Hébert & Carrier, 2007; Kehrle, Sampaio, Granjeiro, de

Table 2Summary of main findings for emotional wellbeing in chronic tinnitus in comparison to control groups ($n = 25$).

Emotional wellbeing	Observed effect in chronic tinnitus	Evidence
Anxiety	<ul style="list-style-type: none"> ● Increased anxiety symptom endorsement than HC and HL ● Similar anxiety symptom endorsement to HC 	<ul style="list-style-type: none"> ● <i>Andersson et al. (2009, 2000, 2003, 2002)</i>; <i>Granjeiro et al. (2013)</i>; <i>Kehrle (2015)</i>; <i>Mannarelli et al. (2017)</i>; <i>Pajor (2013)</i>; <i>Rutter and Stein (1999)</i> ● <i>Araneda et al. (2015)</i>; <i>Heeren et al. (2014)</i>; <i>Mannarelli et al. (2017)</i>; <i>Trevis et al. (2016a)</i>; <i>Waechter and Brännström (2015)</i>
Somatic symptoms	<ul style="list-style-type: none"> ● Similar anxiety symptom endorsement to ENT ● Lower perceived stress than MC ● Lower body image ratings than HC ● Increased somatoform symptoms 	<ul style="list-style-type: none"> ● <i>Rutter and Stein (1999)</i> ● <i>Zirke et al. (2013)</i> ● <i>Stuerz et al. (2009)</i> ● <i>Sahin et al. (2016)</i>
Depression	<ul style="list-style-type: none"> ● Increased depression symptom endorsement than HC, HL, MC ● Similar depression symptom endorsement to HC 	<ul style="list-style-type: none"> ● <i>Andersson et al., 2000</i>, <i>Andersson et al., 2002</i>, <i>Andersson et al., 2003</i>, <i>Andersson et al., 2009</i>; <i>Granjeiro et al. (2013)</i>; <i>Hébert and Carrier (2007)</i>; <i>Kehrle (2015)</i>; <i>Rutter and Stein (1999)</i>; <i>Trevis et al. (2016a)</i>; <i>Weidt et al. (2016)</i>; <i>Zirke et al. (2013)</i> ● <i>Araneda et al. (2015)</i>; <i>Heeren et al. (2014)</i>; <i>Mannarelli et al. (2017)</i>; <i>Pajor (2013)</i>; <i>Waechter and Brännström (2015)</i> ● <i>Rutter and Stein (1999)</i>
HRQoL	<ul style="list-style-type: none"> ● Similar depression symptom endorsement and prevalence to ENT ● Decreased health-related quality of life than HC 	<ul style="list-style-type: none"> ● <i>Weidt et al. (2016)</i> ● <i>Zirke et al. (2013)</i>
Psycho-pathology	<ul style="list-style-type: none"> ● Lower psychological comorbidity than MC overall ● High prevalence of psychiatric problems compared to HC 	<ul style="list-style-type: none"> ● <i>Andersson et al. (2004)</i>
Personality	<ul style="list-style-type: none"> ● Increased neuroticism than HL ● Decreased extraversion than ENT ● Similar psychoticism to HL and ENT, similar extraversion to HL, similar neuroticism to ENT ● Similar personality profile to HC 	<ul style="list-style-type: none"> ● <i>Rutter and Stein (1999)</i> ● <i>Rutter and Stein (1999)</i> ● <i>Rutter and Stein (1999)</i> ● <i>Meric et al. (1998)</i>
Sleep	<ul style="list-style-type: none"> ● Increased psychasthenia than HC ● Increased sleep disturbances than HC ● Less sleep disturbance than MC 	<ul style="list-style-type: none"> ● <i>Bayar et al. (2002)</i> ● <i>Hébert and Carrier (2007)</i> ● <i>Zirke et al. (2013)</i>
Sound sensitivity	<ul style="list-style-type: none"> ● Increased sound sensitivity than HC 	<ul style="list-style-type: none"> ● <i>Hébert and Carrier (2007)</i>

Note: ENT = Ear, nose and throat clinic outpatients, HC = healthy control group, HL = Hearing loss control group, HRQoL = health-related quality of life, MC = medical control group.

Oliveira, & Oliveira, 2015), people with chronic health conditions (*Zirke et al., 2013*), and people with hearing loss (*Rutter & Stein, 1999*). In contrast, similar depressive symptoms were found when comparing people with CT to ENT outpatients (*Rutter & Stein, 1999*), and a minority of studies ($n = 4$) found similar levels of depressive symptoms to HC groups. Unlike studies finding group differences, which recruited from audiology clinics, two of the studies finding no differences sourced participants from non-clinical samples. Specifically, one study recruited from support groups (*Heeren, Maurage, Perrot, De Volder, Renier, Araneda, et al., 2014*), and one study recruited from a combination of clinical and community sources (*Waechter & Brännström, 2015*). Of the two studies finding no differences in depressive symptoms when recruiting from clinical settings, one drew comparisons to cut-off points, rather than a mean difference comparison (*Pajor, Ormezowska, & Jozefowicz-Korczynska, 2013*), while the second specifically excluded people with a psychiatric diagnosis or who were taking psychotropic medications (*Araneda, De Volder, Deggouj, Philippot, Heeren, Lacroix, et al., 2015*). This indicates the importance of considering recruitment strategies and including both clinical and community populations to ensure accuracy in capturing the spectrum of experiences of CT. The importance of this is exemplified by a study demonstrating similarly low symptom endorsement of both HC and CT individuals coping well with their tinnitus, in contrast to the significantly greater endorsement of depression and anxiety symptoms in CT individuals not coping with their tinnitus who were similar to a group of medical controls (chronic headache) (*Kirsch et al., 1989*).

Other aspects of emotional wellbeing have also been investigated, primarily anxiety symptoms, for which there was a similarly strong body of evidence. The majority of studies found greater anxiety symptom endorsement in CT compared to HC groups (e.g. *Andersson et al., 2003*; *Andersson, Eriksson, Lundh, & Lyttkens, 2000*; *Granjeiro, Moura Kehrle, Sarmiento Cardoso de Oliveira, Lopes Sampaio, & Costa Pires de Oliveira, 2013*). Greater anxiety was found in people with CT compared to people with hearing loss, though similar levels were observed when compared to people with other ENT conditions (*Rutter & Stein, 1999*). In contrast, compared to people with other chronic health

conditions, people with CT had less anxiety symptoms (*Zirke et al., 2013*). Of note, three of the studies finding similar levels of anxiety in CT and HC groups also did not find evidence for differences in depressive symptoms noted above, with an additional study recruiting a community sample finding no differences in anxiety, though a significant difference in depressive was identified (*Trevis, McLachlan, & Wilson, 2016a*). Of note, one study found differences for trait anxiety, but not state anxiety (*Mannarelli et al., 2017*) while another found no effect of trait anxiety, but a significant difference in state anxiety ratings (*Kirsch et al., 1989*) indicating the importance of considering the distinction between anxiety at a given moment (state) and anxiety-proneness (trait). Taken together these results suggest that while the level of anxiety experienced by people with CT may be greater than the general population, it may not be experienced to the same extent as other clinical populations. In light of the importance given to anxiety in models of CT, the mixed evidence presented here is not as compelling as expected. It points to the role of other factors modulating the experience of anxiety in CT.

Studies specifically investigating psychopathology in terms of diagnostics rather than symptom endorsement also lend support to the idea of CT falling in a subclinical spectrum with regard to emotional wellbeing. Compared to the general population (i.e., HC) there is evidence suggesting greater prevalence of psychiatric problems in CT, particularly depression, anxiety disorders, phobias and obsessive-compulsive disorder (*Andersson, Carlbring, Kaldø, & Ström, 2004*). In contrast, people with CT have significantly lower rates of psychological co-morbidities than people with chronic medical conditions (asthma, pain and atopic dermatitis), although for all groups the most frequent diagnoses were anxiety/neurotic disorders, somatoform disorders and affective disorders (*Zirke et al., 2013*). Likewise in the domain of sleep quality, a similar pattern is observed, with CT reporting worse quality of sleep than healthy controls (*Hébert & Carrier, 2007*), but better quality of sleep than medical control groups (*Zirke et al., 2013*).

Few studies have branched outside of anxiety, depression and psychiatric diagnoses, largely reflecting the role of anxiety and symptoms of depression in models of CT. However, we did find four studies

investigating personality traits, and two studies addressing other potential psychosomatic symptoms. With regard to personality, while one study found no differences compared to healthy controls (Meric et al., 1998), two subsequent studies using HC groups did identify personality differences in people with CT. Specifically, higher rates of persistent pessimism, hypochondriasis and hysteria have been identified (Marciano, Carrabba, Giannini, Sementina, Verde, Bruno, et al., 2003). Similarly, increased psychasthenia, which captures neuroticism, sensitivity, moodiness and anxiety traits, has been identified in CT (Bayar, Oguzturk, & Koc, 2002). In addition, this study found a broader array of increased personality traits for females reporting CT including hypochondriasis, hysteria, schizophrenia, masculinity/femininity and social introversion traits in addition to psychasthenia. Similarly, a study using medical controls found elevated neuroticism in people with CT compared to people with hearing loss and reduced extraversion in CT compared to ENT outpatients (Rutter & Stein, 1999). Combined, these studies suggest personality traits relating to self-regulation and self-awareness are altered in people with CT. These findings are consistent with the broader tinnitus literature, where elevated personality traits such as introversion, dysphoria and anxious tendencies, and external locus of control have been observed in people with tinnitus (Attias, Shemesh, Bleich, Solomon, Bar-Or, Alster, and Sohmer, 1995; Langguth, Kleinjung, Fischer, Hajak, Eichhammer, and Sand, 2007; Rizzardo, Savastano, Maron, Mangialaio, & Salvadori, 1998; Welch & Dawes, 2008; for a review see Durai & Searchfield, 2016). These particular traits may influence the tendency of an individual to ‘tune in’ to the tinnitus sensation (Welch & Dawes, 2008).

In support of indications that somatic tendencies may be involved in CT, we found a study reporting greater somatoform disorder symptoms in CT (Sahin, Aras, & Yilmaz, 2016). In addition, a study was identified that investigated body image perceptions of people with CT, finding that people with CT reported reduced pleasure and self-confidence in their body and a reduced sense of vitality, although they were not more insecure or concerned about their body than normative data (Stuerz et al., 2009). In addition, one study has reported on sound sensitivity (hyperacusis), finding increased symptoms of hyperacusis in people with CT (Hébert & Carrier, 2007). These studies suggest there may be maladaptive emotional or cognitive associations with body, health or sensory perceptions in CT, which may be involved in maintaining awareness, or perhaps the salience, of the tinnitus sound.

3.2.1.1. Meta-analysis: is emotional wellbeing impaired in individuals with chronic tinnitus? Due to the comparatively large number of studies addressing anxiety and depression symptoms in CT compared to HC we were able to conduct meta-analyses to investigate the observation of reduced emotional wellbeing in CT compared to HC. We identified 12 studies comparing anxiety symptoms between people with CT and HC groups in addition to 12 studies comparing depressive symptoms. This resulted in a total of 331 participants with CT and 248 participants without CT for the anxiety meta-analysis, and 349 people with CT and 266 participants without CT for the depression meta-analysis. Of note, 10 studies reported both anxiety and depression and therefore those populations are represented in both the anxiety and depression meta-analyses. Across these studies there were three measures of anxiety: HADS-A (38%), STAI (38%) and BAI (23%), and two measures of depressive symptoms: BDI (75%) and HADS-D (25%).

The mean effect size for anxiety indicated a moderate difference between groups, with the CT group showing greater anxiety symptoms than people without CT ($d = 0.71$, $SE = 0.12$, $p < 0.001$, Table 3), representing a range of effect sizes from minimal differences between groups ($d = 0.03$) to large ($d = 1.24$) standardised mean difference values. Similarly, the mean effect size for depression suggested a moderately large difference between groups, with the CT group showing more depressive symptoms than those without tinnitus ($d = 0.65$, $SE = 0.14$, $p < 0.001$). Here, effect sizes ranged from minimal, but negative effects (i.e., controls endorsing greater

Table 3

Summary of results from the meta-analyses investigating emotional wellbeing in people with chronic tinnitus compared to healthy controls (d).

Construct	Number of studies	Effect size d (95% CI)	Q (df)	T^2 (95% CI)	Fail-safe N
Anxiety	12	0.71** (0.48, 0.95)	17.38 (11)	0.06 (0.00, 0.35)	240
Depression	12	0.65** (0.37, 0.93)	27.73 (11)*	0.14 (0.03, 0.71)	224

Q = homogeneity statistic, T^2 = estimation of the variance of the true effect.

** $p < 0.001$.

* $p < 0.05$.

depressive symptoms; $d = -0.16$) to large positive effects ($d = 1.76$). This analysis showed evidence of heterogeneity and as such we estimated the distribution of true effects, which indicated that 95% of true effects likely fall between $d = -0.14$ and $d = 1.44$. This suggests diversity within the CT population in endorsing depressive symptoms, although the direction of the effect is highly likely to be in the direction of greater depressive symptoms in CT compared to HC. Differences between the recruitment strategies and inclusion criteria of studies included here may contribute to this broad range. Likewise, it may reflect differences in the sensitivity of various scales used to detect depressive symptoms, as the BDI is a symptom severity measure while the HADS-D is primarily a screening tool. Due to the small number of studies available (< 20) for these analyses, further sub-group analyses to assess possible contributions of measurement tools or recruitment strategies to between-study variation were not justified (Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). Taken together, the current meta-analyses indicate that, in general, people with CT have poorer emotional wellbeing, as reflected in greater anxiety and depressive symptom endorsement, than people without CT (Fig. 5).

We also assessed potential bias due to unpublished or unselected studies with the file drawer analysis (fail-safe N), which suggested robust effects for both the anxiety and depression meta-analyses with > 200 studies with null effects required to reduce the observed significance of the anxiety and depression models to less than $\alpha = 0.05$. The trim-and-fill analysis suggested that four studies ($SE = 2.28$) may be missing from the anxiety analysis with smaller or negative effect sizes, resulting in an adjusted random-effects model with an unbiased effect size of $d = 0.51$ ($SE = 0.13$, $p < 0.001$). For depression, the trim-and-fill analysis suggested no studies were missing ($SE = 2.28$) with smaller or negative effect sizes resulting in an adjusted random-effects model with an unbiased effect size of $d = 0.65$ ($SE = 0.14$, $p < 0.001$). Taken together, these analyses suggest that the observed effects are unlikely to be undermined by publication or availability biases.

3.2.2. Is emotional wellbeing associated with chronic tinnitus severity?

Similar to studies investigating the emotional wellbeing of people with tinnitus compared to people without tinnitus, most studies investigating the correlates of tinnitus severity focused on anxiety and depression (Table 4). In a broad sense, CT has been associated with increased psychological distress across a range of symptoms (Bauch, Lynn, Williams, Mellon, & Weaver, 2003; Hoekstra, Wesdorp, & van Zanten, 2014; Weidt et al., 2016). More specifically, the clear majority of investigations of the association between anxiety and measures of tinnitus impact found evidence of a positive association between increased anxiety and increased CT impact (e.g., Hesser, Bänkestad, & Andersson, 2015; Ooms, Vanheule, Meganck, Vinck, Watelet, and Dhooze, 2012; Zoger, Svedlund, & Holgers, 2006). In addition, one study showed greater CT impact in people with CT and a diagnosed anxiety disorder compared to people with CT who did not have an anxiety disorder (Zirke et al., 2013). Stress has also been associated with tinnitus severity, with recent ecological momentary assessment

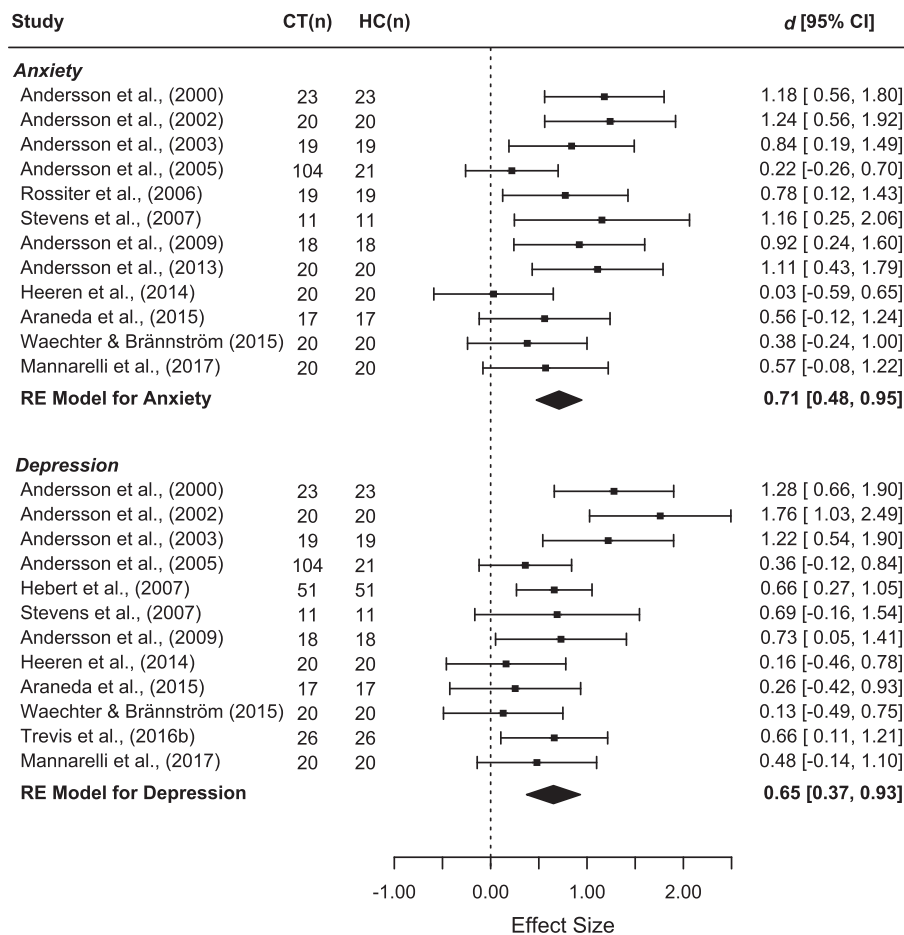


Fig. 5. Forest plot representing results of the meta-analysis investigating the differences in emotional wellbeing between people with chronic tinnitus (CT) and healthy controls (HC). Larger effect sizes (d) indicate poorer emotional wellbeing in the CT group. RE = random-effects.

Table 4

Summary of findings of associations between psychological functions and increased impact of chronic tinnitus ($n = 37$).

Psychological functions	Direction of effect (number of studies)	Authors
Emotional wellbeing		
Anxiety ^a	Positive (25)	*Andersson et al. (2000); *Andersson and Vretblad (2000); *Budd and Pugh (1995); *Crocetti et al. (2009); *Folmer et al. (2008); Goldberg et al. (2017); Granjerio (2013); *Halford and Anderson (1991); *Hesser et al. (2015); Hoekstra et al. (2014); Kehrle (2015); Kirsch et al. (1989); Liu et al. (2015); *Moring et al. (2015); *Ooms et al., 2012, *Ooms et al., 2013; *Rutter and Stein (1999); *Trevis et al. (2016b); *Wallhäusser-Franke et al., 2012, Wallhäusser-Franke et al., 2014; *Zirke et al. (2013); *Zirke et al. (2013); *Zoger et al. (2006)
Bodily symptoms ^{a,b}	Neutral (2)	Gomaa (2014); Pajor (2013)
Depression ^a	Positive (9)	Das et al. (2012); Hoekstra et al. (2014); Kirsch et al. (1989); Newman et al. (1997); Sahin et al. (2016); *Stuerz et al. (2009); *Trevis et al. (2016b); *Wallhäusser-Franke et al., 2012, Wallhäusser-Franke et al., 2014)
Maladaptive coping styles ^a	Positive (25)	*Andersson et al. (2000); *Budd and Pugh (1995); *Crocetti et al. (2009); Das et al. (2012); Granjerio (2013); *Halford and Anderson (1991); Hoekstra et al. (2014); *Folmer et al. (2008); *Hébert and Carrier (2007); *Hesser et al. (2015); *Kehrle et al. (2015); Kirsch et al. (1989); *Meyer et al. (2017); Ooms et al. (2011a); Pajor (2013); *Rutter and Stein (1999); *Stuerz et al. (2009); *Trevis et al., 2016a, *Trevis et al., 2016b; *Wallhäusser-Franke et al., 2012, Wallhäusser-Franke et al., 2014; Weidt et al. (2016); *Zirke et al. (2013); *Zirke et al. (2013); *Zoger et al. (2006)
	Neutral (2)	Gomaa (2014); *Temugan et al. (2016)
	Negative (8)	Andersson (1996); *Budd and Pugh (1995); Cima et al. (2011); *Hesser et al. (2015); Kirsch et al. (1989); *Moring et al. (2015); Stobik et al. (2005); *Zirke et al. (2013)
Maladaptive personality traits	Positive (4)	Caldirola et al. (2016); Meric et al. (1998); *Rutter and Stein (1999); Wallhäusser-Franke et al. (2014)
Obsessive-compulsiveness ^a	Positive (2)	*Folmer et al. (2008); *Trevis et al. (2016b)
Psychopathology ^a	Positive (10)	Andersson et al. (2004); Bartels et al. (2010); Bauch et al. (2003); Kim (2015); Liu et al. (2015); *Milerova et al. (2013); Stobik et al. (2005); *Zirke et al. (2013); *Zirke et al. (2013); *Zoger et al. (2006)
Quality of life ^a	Negative (2)	Cima et al. (2011); Weidt et al. (2016)
Sleep quality ^a	Negative (6)	Fioretti et al. (2013); *Hébert and Carrier (2007); Liu et al. (2015); Stobik et al. (2005); *Wallhäusser-Franke et al. (2012); *Zirke et al. (2013)
Sound sensitivity	Positive (2)	Fioretti et al. (2013); *Hébert and Carrier (2007)

^a Indicates evidence sourced from both correlations and comparisons between low and high impact subgroups.

^b Bodily symptoms include pain, somatisation, hypochondriasis and body image.

data suggesting tinnitus severity and stress vary over time together (Goldberg, Piccirillo, Nicklaus, Skillington, Lenze, Rodebaugh, et al., 2017; Gomaa, Elmagd, Elbadry, & Kader, 2014). Post-traumatic stress disorder (PTSD) has also been investigated with regard to CT, with findings indicating greater CT impact for people with CT and PTSD than those without PTSD (Fagelson, 2007; Liu, Hu, Streelman, & Guthrie, 2015). Of note two studies did not find an association between anxiety and severity. While both studies showed small correlations with anxiety and depression, only one reached significance for depression (Pajor et al., 2013), while the other was non-significant for both anxiety and depression (Gomaa et al., 2014). These contrary results likely reflects the use of visual analogue scales not validated for category formation to create multiple groups of tinnitus severity potentially masking clear trends reaching significant levels (Gomaa et al., 2014). Combined, this body of work offers strong support for the theory that anxiety is associated with the severity of impact that CT can have on an individual.

Similar to the findings for anxiety, the vast majority of investigations of the association between depressive symptoms and measures of tinnitus impact found evidence of a positive association between increased depressive symptoms and increased CT impact (e.g., *Crocetti et al., 2009; *Halford & Anderson, 1991; *Meyer, Neff, Grest, Hemsley, Weidt, and Kleinjung, 2017; *Zoger et al., 2006). One study investigated CT impact in people with and without depression, finding that individuals with co-morbid CT and depression reported greater tinnitus impact than people without co-morbid depression (*Zirke et al., 2013; Folmer, Griest, Meikle, & Martin, 1999). Similarly, people with CT and seasonal affective disorder reported greater CT impact than people without co-morbid seasonal affective disorder (Kim, 2015). Contrary to the majority of studies two report a non-significant relationship between depression and tinnitus severity (*Temugan, Yildirim, Onat, Susuz, Elden, Unsal, et al., 2016; Gomaa et al., 2014). While Gomaa et al. (2014) is noted above, *Temugan et al. (2016) suggest the weak association observed had clinical relevance for their sample. As such, these studies provide replicable, consistent evidence for an association between depressive symptoms and the impact of CT.

A smaller number of studies have considered the links between CT and a possible role of somatisation, whereby poor psychological functioning is expressed with regard to altered body, health or sensory perceptions. In support of a link between bodily symptoms and the severity of CT, it has been associated with greater somatisation tendencies and perceived pain, as well as increased hypochondriasis and illness attitudes (e.g., *Trevis et al., 2016b; *Wallhäuser-Franke et al., 2012). In addition, there is evidence supporting a relationship between CT and increased sensitivity to external sounds (*Hébert & Carrier, 2007). Comparison of subgroups with high and low CT impact scores found that people with greater tinnitus impact had more concerns and insecurity about their bodies, and perceived themselves as less healthy (*Stuerz et al., 2009). Similarly more severe impact of CT was present in a subgroup of people also diagnosed with a somatoform disorder, than people without a co-morbid somatoform disorder (*Zirke et al., 2013). While these results span a broad range of symptoms and approaches to assessing the relationship between the impact of CT and bodily symptoms, they suggest a relationship exists between the impact of CT and individuals body perceptions, both in a physical sense and as a means of expressing poor emotional wellbeing.

Additional areas of investigation include sleep and obsessive compulsive tendencies, coping strategies and personality. Research suggests increased tinnitus impact is associated with poor sleep, a feature sometimes linked with mood and bodily symptoms (e.g., Fioretti, Fusetti, & Eibenstein, 2013; Miguel, Yaremchuk, Roth, & Peterson, 2014). In addition, severity of tinnitus in CT has been associated with increased obsessive-compulsive tendencies, and is thought to be linked to broader difficulties in self-regulation and habituation (*Folmer, Griest, & Martin, 2008; *Trevis et al., 2016b). Acceptance has been identified as an adaptive coping strategy with individuals higher in acceptance showing less CT impact (*Hesser et al., 2015; *Moring,

Bowen, Thomas, & Joseph, 2015). In contrast evidence suggests catastrophising thoughts about CT are maladaptive, showing a strong negative correlation with increased CT impact (Cima et al., 2011). Greater resilience, 'hardiness', and optimism have both been associated with reduced CT severity, suggesting these adaptive or 'positive' traits may be beneficial in coping with CT (Andersson, 1996; Kirsch et al., 1989; Wallhäuser-Franke et al., 2014). Some maladaptive personality traits have also been associated with increased CT impact, particularly individuals who endorse distressed, depressive, hysterical, neurotic or extraverted personality traits (*Rutter & Stein, 1999; Bartels, Pedersen, van der Laan, Staal, Albers, and Middel, 2010; Meric et al., 1998). In addition, depressive coping strategies, such as retreating, worrying attitudes, and a more external locus of control, whereby individuals attribute outcomes to factors beyond their control, have been identified as maladaptive (*Budd & Pugh, 1995; Caldirola, Teggi, Daccò, Sangiorgio, Bussi, and Perna, 2016; Stobik, Weber, Münte, Walter, & Frommer, 2005). These results further reinforce the notion that more severe impact of CT is associated with emotional wellbeing in a broad sense, including functional aspects of daily life (e.g., sleep), our coping abilities, and our personality.

3.2.2.1. Meta-analysis: is emotional wellbeing associated with severity of chronic tinnitus? As in our investigations regarding the presence of CT, there was a suitably substantial body of work addressing the correlations between indicators of emotional wellbeing and the impact of CT to conduct a meta-analysis of these effects. We identified 18 eligible studies reporting the association between anxiety symptoms and CT impact, and 19 eligible studies reporting the association between depressive symptoms and CT impact. This resulted a total of 5063 participants and 19 coefficients for the anxiety analysis, and 4475 participants and 20 coefficients for the depression analysis. Of note, 13 studies reported both anxiety and depression results and therefore those populations are represented in both analyses. The two most commonly used measures of CT impact were the THI (41%) and the TQ (33%, including short versions of the TQ). The two most common measures of anxiety were the STAI (42%) and the HADS-A (21%), and for depression they were the BDI (63%) and the HADS-D (21%).

For anxiety we found a moderately strong positive correlation with the impact of CT ($r = 0.52$, $SE = 0.03$, $p < 0.001$, Table 5), capturing a range of effect sizes from small ($r = 0.28$) to strong ($r = 0.67$) correlation coefficients. We also found a moderately strong positive correlation between depressive symptoms and the impact of CT ($r = 0.51$, $SE = 0.05$, $p < 0.001$), with observed effect sizes ranging from small ($r = 0.27$) to large ($r = 0.74$). As both analyses exhibited evidence of significant heterogeneity, we estimated the distribution of true effects. For anxiety, this indicated that 95% of true effects likely fall between $r = 0.33$ and $r = 0.68$, with a broader range identified for depression ($r = 0.18$ and $r = 0.73$). This suggests diversity within the CT population in reporting the strength of association between CT impact and emotional wellbeing, although the direction of this effect is highly likely to be positive. The variety of measures used, and their sensitivity in assessing symptoms of anxiety, depression and tinnitus impact, may

Table 5

Summary of results from the meta-analyses investigating the relationship between emotional wellbeing and the impact of chronic tinnitus.

Construct	Number of studies	Effect size r (95% CI)	Q (df)	T^2 (95% CI)	Fail-safe N
Anxiety	18	0.52** (0.47, 0.57)	76.37 (17)**	0.01 (0.00, 0.03)	9832
Depression	19	0.51** (0.43, 0.58)	135.73 (18)**	0.03 (0.01, 0.07)	8855

Q = homogeneity statistic, T^2 = estimation of the variance of the true effect.

** $p < 0.001$.

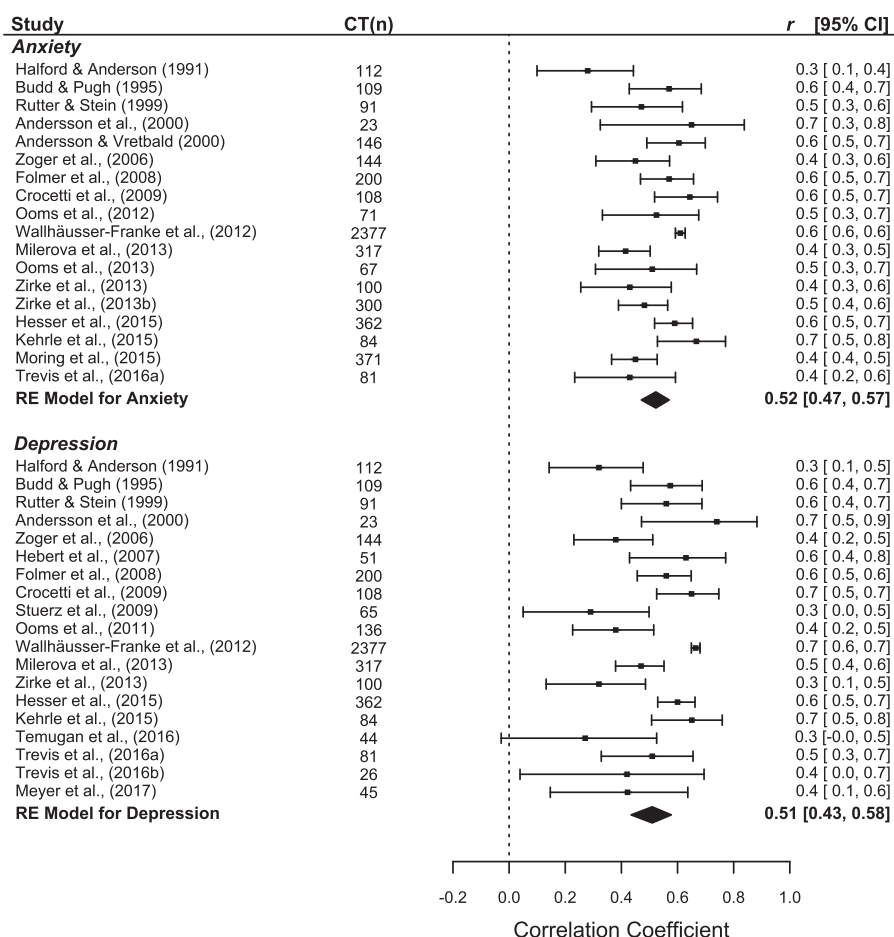


Fig. 6. Forest plot representing results of the meta-analyses on the correlation between emotional wellbeing and the impact of tinnitus in people with chronic tinnitus (CT). Higher correlation (r) values represent stronger associations. RE = random-effects.

account for some of the variation in correlation coefficients. In addition, the range of inclusion criteria and recruitment strategies employed may contribute to the heterogeneity between studies. Due to the small number of studies available (< 20) for these analyses, further subgroup analyses based on measurement tools or recruitment strategies were not justified (Huedo-Medina et al., 2006). Overall, the current meta-analyses indicate that people experiencing a more severe impact of CT are more likely to also report increased symptoms of anxiety and depression (Fig. 6).

We assessed publication bias using a file-drawer analysis which indicated a substantive body of work with null effects would be required to reduce the observed significance of the anxiety and depression models to less than $\alpha = 0.05$. The trim-and-fill analyses estimated there were no missing studies with negative or null effects in the anxiety meta-analysis ($SE = 2.48$) resulting in an adjusted random-effects model with an unbiased effect size of $r = 0.53$ ($SE = 0.03$, $p < 0.001$). This analysis also estimated no studies were missing with a negative or null correlation in the depression meta-analysis ($SE = 2.73$), resulting in an adjusted random-effects model with an unbiased effect size of $r = 0.51$ ($SE = 0.05$, $p < 0.001$). As such, these analyses indicate it is highly unlikely the observed effects have been substantially undermined by publication or availability biases.

3.2.3. Summary of emotional wellbeing in chronic tinnitus

Overall, we have identified support for a role of impaired emotional wellbeing in CT. Across a broad range of emotional wellbeing factors, people with CT typically reported reduced emotional wellbeing compared to HC, though a more sub-clinical profile typically emerged in comparison to medical and hearing loss controls. These results suggest reduced emotional wellbeing may contribute to the ongoing awareness

of the tinnitus sensation. Moreover, reduced emotional wellbeing was also consistently associated with increased severity of the impact of tinnitus in the CT population. The effect sizes observed in our meta-analyses and noted in the studies reviewed typically represent moderate effect sizes, suggesting it is reasonable to attribute the association to shared symptoms and/or mechanisms underpinning emotional wellbeing and CT severity, rather than a methodological artefact. This is consistent with a pivotal longitudinal study by Hébert et al. (2012), which found co-variation between depression and tinnitus prevalence in the general population over a 2-year period. The consistency and effect sizes found in this review, in addition to longitudinal work, indicates that the relationship between emotional wellbeing and CT may reflect a shared mechanism and/or common symptoms, rather than methodological artefact.

Importantly, the relatively well replicated finding of increased depression and anxiety in people with CT compared to people without CT is also prominent in population level studies, suggesting this effect is typically robust to recruitment strategies, though the size of the effect may be inflated in clinical samples. Research shows that people with CT who do not seek help (i.e., community samples) show increased psychiatric symptoms, particularly obsessive-compulsive tendencies, compared to HC, with a similar though less severe profile to people who seek help for CT (i.e., clinical samples) (Attias et al., 1995). In particular, increased depression, anxiety, and somatisation markers (e.g. bodily pain) have been reported in population studies spanning Sweden (Baigi, Oden, Almlid-Larsen, Barrenas, & Holgers, 2011; Hébert et al., 2012), the UK (McCormack, Edmondson-Jones, Fortnum, Dawes, Middleton, Munro, and Moore, 2014), Norway (Krog, Engdahl, & Tambs, 2010), Korea (Kim, Lee, An, Sim, Park, Kim, et al., 2015) and the USA (Bhatt, Bhattacharyya, & Lin, 2016; Nondahl et al., 2007, Nondahl,

Cruikshanks, Huang, Klein, Klein, Javier Nieto, and Tweed, 2011; Shargorodsky, Curhan, & Farwell, 2010), though some studies report much smaller effect sizes than those observed in CT populations, particularly after controlling for demographic features (e.g., Krog et al., 2010). Depression and anxiety in such studies have been noted both in terms of increased risk or prevalence compared to people without tinnitus, as well as correlates of increased severity (e.g., Bhatt et al., 2016).

Differentiating shared symptoms from underlying mechanisms will be important for future work in characterising the precise nature of this relationship. Based on the array of emotional wellbeing features implicated here, a shared mechanism likely underpins the commonalities in presentation between these conditions. Specifically, we propose that functional disruption to neurocognitive networks may be a core contributor. Disruption to large-scale neurocognitive networks associated with salience, emotional regulation and goal-directed behaviours have been implicated in a number of chronic conditions, phantom perceptions, and psychological processes including chronic pain, depression, anxiety and the use of coping strategies (Bushnell, Čeko, & Low, 2013; De Ridder et al., 2011; Derryberry & Reed, 2002; Lutz, Herwig, Opialla, Hittmeyer, Jancke, Rufer, et al., 2014; Menon, 2011; Rayner, Jackson, & Wilson, 2016). In the clinical sense, a patient presenting with CT and symptoms of fatigue, apathy and poor sleep should also be assessed for co-morbid depression (Langguth, Goodey, Azevedo, Bjorne, Cacace, Crocetti, et al., 2007). Importantly the results of the present review and other work suggest it is also feasible the patient may be sub-clinical for depression with the symptoms representing a severe impact of CT rather than co-morbid depression. In this case, the CT patient will likely benefit from strategies to reduce these symptoms (Cima et al., 2012), which in turn may also decrease the impact of tinnitus on day-to-day life and potentially awareness of the sensation.

3.3. Cognitive functioning in people with chronic tinnitus ($n = 16$)

Sixteen studies investigating the cognitive functioning in CT were identified in the present review using objective measures, with two of these studies also reporting subjective assessments of cognitive abilities. Eighty-one percent of studies investigating cognitive functioning compared people with CT to HC groups or normative data, no studies were found comparing cognitive functioning in CT to clinical control groups. Thirty-eight percent of cognitive investigations addressed the association between cognitive functioning and the severity of tinnitus; with one study (6%) performing a subgroup analysis to address this relationship. Investigations of general cognitive function have found no evidence of general cognitive decline in people with CT compared to normative data and HC (*Mannarelli et al., 2017; Pajor et al., 2013). By investigating more specific aspects of cognitive functioning with regard to the presence of CT (Section 3.3.1.) and the severity of its impact (Section 3.3.2), the work summarised below elucidates evidence of more subtle indicators that cognitive functioning may be involved in chronic tinnitus.

3.3.1. Is cognitive functioning associated with ongoing awareness of chronic tinnitus?

Relatively consistent evidence for impaired attention processing in CT (89%) has been found, while there is mixed evidence for memory impairments, with only 50% of memory studies indicating impaired performance in CT. As can be seen in Table 6, investigations of attention functions consistently found slower reaction times in people with CT on tasks assessing various aspects of attention. These aspects have included selective and divided attention (e.g., *Andersson et al., 2002; *Stevens, Walker, Boyer, & Gallagher, 2007), biased information processing (e.g., *Andersson et al., 2005; *Ooms, Vanheule, Meganck, Vinck, Watelet, and Dhooge, 2013, and higher-level control of attention and attention switching (e.g., *Heeren et al., 2014; *Trevis et al., 2016a; Pajor et al., 2013). A few of these studies also analysed performance accuracy, typically revealing reduced accuracy in CT groups,

however these findings are tempered by the relatively small number of errors suggesting that overall, CT participants were still very capable of performing the tasks accurately (*Heeren et al., 2014).

A notable exception to these findings is the work of *Waechter and Brännström (2015) who found no differences in accuracy or reaction time on a Stroop task between their CT and HC groups. The main point of difference in this study was recruitment of healthy-hearing individuals only. As a result, this study raises the issue of whether general hearing ability may be impacting cognitive performance. While possible hearing differences between groups are not reported in all studies of attention in CT, there is evidence of cognitive difficulties in hearing matched groups, and most tasks utilised visual attention rather than tasks which have a hearing component (*Araneda et al., 2015). Similarly, recent work from our group found reduced cognitive control using a hearing matched control group, and this effect remained after controlling for hearing ability, and the presence of background noise (i.e., the tinnitus sensation) suggesting hearing health or the presence of a potential distracting sound may not account for such discrepancies (*Trevis et al., 2016a). As such while hearing abilities may be a potential confound in tinnitus research this should not necessarily undermine compelling findings. The inclusion of separate comparison groups with hearing loss in addition to healthy-hearing control (i.e., HC) groups provides a way of assessing possible interactions between hearing health, cognitive functioning, and the presence of CT.

In contrast, there appears to be mixed evidence for memory impairments in CT, possibly reflecting the diversity of study methods. While some studies report impairments in working memory processes (*Rossiter, Stevens, & Walker, 2006; Pierce, Kallogjeri, Piccirillo, Garcia, Nicklaus, and Burton, 2012), others demonstrate no impairments for short or long delays in memory recall tasks (*Andersson et al., 2009; *Trevis et al., 2016a; Pierce et al., 2012). Verbal fluency assessments have also found no differences between people with and without CT, which is an important finding given the language component of some memory tests (Pierce et al., 2012). These mixed results may reflect variation in the type of tasks used, control groups used, or a possible moderating factor such as performance anxiety.

There is also evidence to suggest autobiographical memory is impaired in CT compared to HC (*Andersson et al., 2003). Within the broader tinnitus literature, people with tinnitus have been shown to have a similar ability to people currently experiencing depression on this task. However, the error profile for people with tinnitus was different to the error profile commonly seen in depressed individuals, with the specific type of errors made by the tinnitus group proposed to reflect impaired executive control (e.g., association based errors and failure to generate an autobiographical memory; Andersson, Hesser, Cima, & Weise, 2013). On a related note, people with CT have also been found to generate more negative future thoughts than people without CT, which is also symptomatic of depression and thought to rely on similar neural substrates as autobiographical memory within an integrative, reflective 'prospective brain' network (Andersson, Kyrre Svalastog, Kaldo, & Sarkohi, 2007; Rayner et al., 2016; Schacter, Addis, & Buckner, 2007). Combined, the current findings provide mixed evidence for CT involving, and perhaps therefore limiting, working memory resources. In contrast there was no reported evidence supporting disruption of more stable memory networks in CT.

3.3.2. Is cognitive functioning associated with chronic tinnitus severity?

Seven studies have investigated aspects of cognitive functioning on the severity of CT. Six studies focused on attention, with four studies finding a relationship between increased tinnitus impact and poorer performance on attention demanding tasks (e.g., *Heeren et al., 2014; Das, Wineland, Kallogjeri, & Piccirillo, 2012). While *Trevis et al. (2016a) reported a positive correlation based on their full CT sample, Das et al. (2012) only reported correlations for a sub-group of participants reporting high CT impact where they also found a positive association between CT impact and cognitive functioning. The remaining

Table 6
Summary of main findings for cognitive functioning in chronic tinnitus ($n = 16$).

Cognitive functions	Cognitive measures ^a	Observed effect in chronic tinnitus	Evidence
<i>Differences between people with and without chronic tinnitus ($n = 14$)</i>			
Attention processes	<ul style="list-style-type: none"> • ANT, D-ST, <i>n</i>-back, divided attention task, Stroop task, stimulus detection paradigm, SST, TMT • Stroop task 	<ul style="list-style-type: none"> • Impaired performance on attention demanding tasks compared to HC. • Similar performance on attention demanding tasks to HC. 	<ul style="list-style-type: none"> • *Araneda et al. (2015); *Andersson et al. (2000,2002); *Heeren et al. (2014); Pajor (2013); *Rossiter et al. (2006); *Stevens et al. (2007); *Trevis et al. (2016a) • *Waechter and Brännström (2015)
Cognitive bias	<ul style="list-style-type: none"> • Emotional Stroop task 	<ul style="list-style-type: none"> • Faster responses to tinnitus-words indicating information bias in CT. 	<ul style="list-style-type: none"> • *Andersson et al. (2005)
General cognitive function	<ul style="list-style-type: none"> • MMSE 	<ul style="list-style-type: none"> • Similar performance to HC/normative data 	<ul style="list-style-type: none"> • *Mannarelli et al. (2017); Pajor (2013)
Memory	<ul style="list-style-type: none"> • AMT, CVLT, RST • CVLT, DST, Serial recall task 	<ul style="list-style-type: none"> • Impaired autobiographical memory, working memory (and learning rate) compared to HC. • Similar short term and delayed recall to HC. 	<ul style="list-style-type: none"> • *Andersson et al. (2003); Pierce et al. (2012); *Rossiter et al. (2006)
Verbal fluency	<ul style="list-style-type: none"> • COWAT, SRB:1 	<ul style="list-style-type: none"> • Similar verbal fluency to HC. 	<ul style="list-style-type: none"> • *Andersson et al. (2009); Pierce et al. (2012); *Trevis et al. (2016a) • *Andersson et al. (2009, 2003); Pierce et al. (2012)
<i>Correlates with tinnitus severity ($n = 7$)</i>			
Attention	<ul style="list-style-type: none"> • ANT, BST, Stroop • <i>n</i>-back, TMT, Stroop 	<ul style="list-style-type: none"> • Worse attention associated with greater severity (4) • No association (3) 	<ul style="list-style-type: none"> • *Araneda et al. (2015); Das et al. (2012); *Heeren et al. (2014)^b; *Stevens et al. (2007) • *Araneda et al. (2015); Pajor (2013); *Trevis et al. (2016a)
Affective priming	<ul style="list-style-type: none"> • Affective Priming Task 	<ul style="list-style-type: none"> • Positive (1) 	<ul style="list-style-type: none"> • *Ooms et al. (2013)

Note: CT = chronic tinnitus, DC = depressed controls, HC = healthy controls.

^a Cognitive measures: AMT = Autobiographical Memory Test, ANT = Attention Network Test, BST = Brain Speed Test, COWAT = Controlled Oral Word Association Test, CVLT = California Verbal Learning Test, DST = Digit Span Task, D-ST = Digit Symbol Test, RST = Reading Span Test, SRB:1 = Synonym Verbal Ability Test, SSRT = Stop Signal Task.

^b This correlation was found specifically with the intensity of tinnitus coping strategies.

two studies only found correlations between cognitive performance and (a) subscales of CT impact measures relating to duration of CT and coping strategies (*Heeren et al., 2014), or (b) visual analogue scale rating annoyance with CT, but not the full CT impact measure (*Araneda et al., 2015). As such, while there is some preliminary evidence supporting a possible relationship between attention and the severity of CT, it is inconclusive at this point and more systematic assessment of this relationship is required. In addition to the above objective cognitive measures, one study has shown that people with high-CT impact have reported greater subjective concentration difficulties compared to a low-CT impact subgroup (Stobik et al., 2005), consistent with evidence that people with CT report more subjective cognitive complaints than HC (*Andersson et al., 2009; *Trevis et al., 2016a).

Additional investigations of cognitive functioning with regard to the impact of CT have tended to incorporate emotive factors. For example, people with high self-directed attention (which has also been considered an aspect of somatisation) have been found to have a more negative tinnitus impact than people with lower self-directed attention (Newman, Wharton, & Jacobson, 1997). In addition, dysfunctional automatic processing of affective information has been associated with increased CT impact. Specifically, people with a higher CT impact had increased automatic processing of fearful and angry affective primes, and reduced automatic processing of happy affective primes compared to people with low CT impact (*Ooms et al., 2013). These studies suggest cognitive factors may play a role in the impact CT can have on an individual, particularly when considering the associations and interactions between cognitive and emotion regulation.

3.3.3. Summary of cognitive functioning in chronic tinnitus

As there are still only a limited number of studies spanning the broad area of cognition, more research is required in this area within domains of cognitive functioning (e.g., inhibitory control, memory, cognitive control/executive functions, information processing). Based on the limited number of studies using similar tasks, or assessing common cognitive domains, a meta-analysis was not appropriate for this topic. Targeted research using gold-standard cognitive tasks known to rely on specific cognitive domains and associated neural networks

will strengthen our understanding of the contribution of specific aspects of cognitive functioning to the persistent presence of CT.

One interpretation of the above cognitive results is that impaired attention and working memory in CT is symptomatic of a hypoactive cognitive control network, which allocates cognitive resources. In contrast, self-directed attention, affective priming and poor performance on autobiographical memory tasks may be symptomatic of a hyperactive autobiographical memory network, also known as the default mode network in its 'resting-state' form, which underpins rumination and introspection (Rayner et al., 2016). These antithetical networks have a dynamic relationship, with the more goal-directed or 'task positive' cognitive control network typically activating to achieve optimal task performance and to reduce introspection, reflected in deactivation of the autobiographical memory network or 'task-negative' network (Rayner et al., 2016). In this interpretation, reduced cognitive functioning may maintain the tinnitus sensation due to dysregulation of these neurocognitive networks preventing individuals from switching attention away from the tinnitus sensation, which in turn may increase its perceived severity.

An alternative explanation is that cognitive impairments result from the tinnitus sensation and associated negative emotions consuming finite cognitive resources and distracting participants from proficient task performance. In this interpretation, reduced cognitive functioning is a result, or symptom, of CT. Investigations aimed at determining whether impaired cognitive functioning actively maintains awareness of CT (e.g., a failure to re-direct cognitive resources), or is a result of the presence of the tinnitus sound (e.g., distraction) are required. Determining the extent of cognitive involvement, and its role as a causative mechanism or a by-product of CT will be crucial to further developing our understanding of the role of cognition in the presence of CT.

3.4. The interaction of cognitive functioning and emotional wellbeing

Few studies have investigated links between emotional wellbeing and findings of cognitive difficulties in CT, however the studies that have investigated this have found current emotional wellbeing may

contribute to cognitive performance. Specifically, studies accounting for emotional wellbeing in group comparisons have found that current depressive symptoms accounted for some of the impairment observed in the CT group compared to HC on an autobiographical memory task (*Andersson et al., 2003), and have been associated with task performance (*Andersson et al., 2002). In contrast, other work has found cognitive effects robust to emotional wellbeing covariates (*Heeren et al., 2014; *Trevis et al., 2016a). In addition, an investigation of the relationship between anxiety and cognitive performance on attention and memory tasks found no association between anxiety and task ability for people with CT (*Rossiter et al., 2006; *Stevens et al., 2007). Though it is important to note some cognitive investigations exclude people with a history of poor emotional wellbeing in order to elucidate cognitive mechanisms in a homogenous sample, as such, this may mask potential emotional-cognitive interaction effects in the broader CT population (e.g., *Araneda et al., 2015; *Waechter & Brännström, 2015). Combined, these results suggest future studies of cognitive functioning comparing people with and without tinnitus should consider the role of emotional wellbeing, particularly mood, on both cognitive performance and CT factors. In particular, current emotional states may impact the relationship between cognitive functioning and CT, perhaps as mediators or moderators.

3.5. Manipulating the intrusiveness of chronic tinnitus

Two studies have manipulated awareness of tinnitus (e.g., thought suppression tasks) within tinnitus groups (i.e., within-subject designs). An initial study from the broader tinnitus literature found that people with tinnitus who were instructed to suppress tinnitus-related thoughts showed a subsequent decrease in tinnitus intrusion, while those told to attend to tinnitus-related thoughts showed a subsequent increase in tinnitus intrusion (Andersson, Jüris, Classon, Fredrikson, & Furmark, 2006). Further investigations in people with CT have compared suppression instructions with the instruction to accept or 'welcome' tinnitus-related thoughts with results indicating acceptance of tinnitus thoughts is associated with decreased tinnitus intrusion (Westin, Hayes, & Andersson, 2008). In a similar vein, manipulation of whether participants had control of background sounds or not while doing tasks has shown increased tinnitus interference and slower task improvement in people with sound control (Hesser, Pereswetoff-Morath, & Andersson, 2009). The results of these studies suggest there may be a link between (perceived) control of cognitive resources and the intrusiveness of tinnitus. This is consistent with earlier evidence indicating that a failure of higher-order control of cognitive resources may contribute to impaired performance by people with CT across a range of cognitive tasks (see Table 6). Unpacking the links between cognitive control (perceived or objective) and emotion regulation may help identify how cognitive control and emotion regulation contribute to the chronicity of the tinnitus sensation.

3.6. Psychological predictors and mediators of chronic tinnitus impact

A growing number of studies have extended the work on psychological factors associated with the impact of CT to consider factors that may be predictive of its impact (Table 7). Perhaps unsurprisingly, both anxiety and depression have been found to predict the severity of the impact of CT (e.g., *Andersson & Vretblad, 2000; *Oishi, Shinden, Kanzaki, Saito, Inoue, and Ogawa, 2011; Ooms, Meganck, Vanheule, et al., 2011a; Unterrainer, Greimel, Leibetseder, & Koller, 2003). Potential psychosomatic and bodily aspects have been found to be predictive of CT impact, including somatisation (*Milerova, Anders, Dvorak, Sand, Koniger, and Langguth, 2013) and sleep (Fioretti et al., 2013). In the broader tinnitus literature both illness representations and pain have also been found to predict tinnitus severity (Erlandsson & Holgers, 2001; Vollmann, Kalkouskaya, Langguth, & Scharloo, 2012). Coping strategies and personality traits have also been found to be

predictive of CT impact, primarily greater internal locus of control (Unterrainer et al., 2003), and the increased endorsement of personality traits, namely greater resilience (Wallhäusser-Franke et al., 2014) and increased endorsement of a distressed/volatile personality type (Bartels et al., 2010). In addition, tinnitus impact was found to predict increased depression, anxiety sensitivity, and reduced quality of life (*Moring et al., 2015; *Zeman et al., 2014; Weidt et al., 2016).

Of note, one study investigated both cognitive functioning and emotional wellbeing in the same population, finding that processing speed on a cognitively demanding task and emotional wellbeing (somatisation and depression) were predictive of perceived CT impact (Das et al., 2012). In addition, one study used a discriminant function analysis to identify factors able to discriminate cases with and without CT, which identified cognitive control and depressive symptoms as core predictors of ongoing tinnitus awareness (*Trevis et al., 2016a). While less research has focused on the predictors of CT, these few studies suggest that psychological functioning; primarily reduced emotional wellbeing, may precipitate and/or maintain the ongoing awareness and severity of tinnitus in this chronic population. Longitudinal research in people with tinnitus, and in populations with reduced emotional wellbeing (e.g., depressed or anxious individuals) who may be at greater risk of developing tinnitus are required to investigate the possibility of bi-directional relationship.

Recent work has explored the role of mediator variables in the relationships between psychological factors and the impact of CT. As shown in Fig. 7, while personality traits have been found to predict the impact of CT, it has been shown that current emotional wellbeing, namely anxiety, depression, or somatisation tendencies, mediate this relationship (*Trevis et al., 2016b; Bartels et al., 2010; Wallhäusser-Franke et al., 2014). Combined, these studies suggest that more stable traits, such as resilience or anxiety-proneness may be drive emotion (dys)regulation and associated negative thoughts, which in turn may increase the severity of the impact of CT. In other words, current emotional and cognitive states may mediate the relationship between stable traits and tinnitus severity. This is consistent with the broader tinnitus literature, where catastrophising or negative self-instructions, a maladaptive coping strategy, partially mediated the relationship between an individual's illness representations, particularly emotional associations and perceived consequences, and the perceived impact of tinnitus (Vollmann et al., 2012). Studies employing such analyses lend support to the idea that there is more complexity to the relationships between emotional wellbeing and CT impact than is modelled in many current analyses. As such there is a need to systematically examine the complexity of such relationships, to determine the role(s) of various aspects of psychological functioning on the severity of impact of CT.

4. General discussion

The results of this review highlight the importance of incorporating psychological functioning, particularly with regard to emotional wellbeing and cognition, into theories, research, and healthcare interventions for people with CT. In reviewing the literature, there is a clear focus on emotional wellbeing predominantly targeting anxiety and depression when investigating both the presence of CT and its impact. In addition, there appears to be growing interest in cognitive functioning, personality, and the role of mediating factors in these relationships, all aiming to develop our understanding of the factors associated with the impact of CT, and the factors maintaining awareness of tinnitus.

Core findings from this review include support for a relationship between anxiety and CT, and similarly, a relationship between depression and CT. Anxiety has been implicated as a key factor in early models of tinnitus (Jastreboff et al., 1996), and while there was some mixed support for significant differences in anxiety symptoms between people with and without CT, the majority of work and meta-analyses provide reasonable evidence for a moderate association between

Table 7
Summary of findings of psychological predictors of the impact of chronic tinnitus (n = 15).

Predictor	Number of studies	Supporting evidence
<i>Predictors of chronic tinnitus impact (n = 14)</i>		
Increased depressive symptoms	10	Bartels et al. (2010); Das et al. (2012); *Hesser et al. (2015); Hoekstra et al. (2014); *Milerova et al. (2013); *Oishi et al. (2011); Ooms et al. (2011a); *Trevis et al. (2016b); Unterrainer et al. (2003); *Wallhäusser-Franke et al. (2012)
Increased anxiety or worry	8	*Andersson et al. (2000); Bartels et al. (2010); Caldirola et al. (2016); *Hesser et al. (2015); Hoekstra et al. (2014); *Oishi et al. (2011); *Trevis et al. (2016b); *Wallhäusser-Franke et al. (2012)
Increased report of pain and somatisation	4	Das et al. (2012); Hoekstra et al. (2014); *Milerova et al. (2013); *Wallhäusser-Franke et al. (2012)
Decreased sleep quality	2	Fioretti et al. (2013); *Wallhäusser-Franke et al. (2012)
Increased maladaptive coping styles (internal locus of control)	1	Unterrainer et al. (2003)
Personality traits of distressed-type (increased) and resilience (decreased)	2	Bartels et al. (2010); Wallhäusser-Franke et al. (2014)
Decreased processing speed	1	Das et al. (2012)
<i>Predictors of chronic tinnitus presence (n = 1)</i>		
Increased depressive symptoms	1	*Trevis et al. (2016a)
Decreased cognitive control	1	*Trevis et al. (2016a)

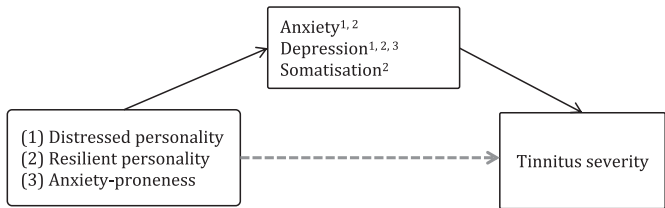


Fig. 7. Summary of the mediating effects of current emotional wellbeing on the relationships between stable personal attributes and tinnitus impact. Note:¹ denotes mediating factors associated with distressed personality characteristic, ² denotes mediating factors associated with resilient personality characteristic, ³ denotes mediating factors associated with anxiety-proneness.

increased anxiety and the presence and impact of CT. Consistent with observed similarities in the clinical presentation of depression and CT such as lack of sleep, low mood, concentration difficulties, headaches consistent evidence emerged from this review, supported by meta-analyses, suggesting increased depressive symptoms are associated with both the presence and severity of CT (Langguth, Landgrebe, Kleinjung, Sand, & Hajak, 2011).

This review has established consistent evidence supporting a role of a variety of cognitive functions in CT. As highlighted in Fig. 8, there has been substantial overlap in the aspects of psychological functioning that have been investigated, and found to influence the presence and impact of CT. Cognitive factors are more dominant with regard to the presence of CT, though this may reflect fewer investigations of the role of

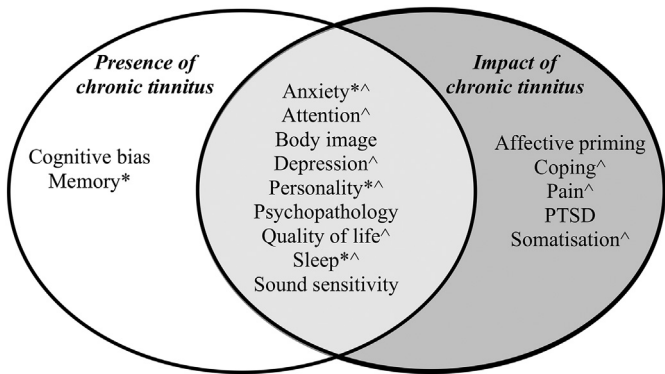


Fig. 8. Venn diagram highlighting the contribution of psychological factors found to be impaired in people with chronic tinnitus, and/or associated with its impact. Note: ^ = factors that are also predictive of chronic tinnitus impact; * = factors with mixed evidence for a role in the presence of chronic tinnitus.

cognitive factors in the impact of CT. In contrast, coping strategies and bodily symptoms appear to be more influential on the impact of CT. Given the overlap of psychological functions that may influence both the presence and the impact of CT, a crucial next step is to understand the complexity of relationships between cognitive and emotional factors to elucidate potential roles or interactions between these psychological functions as mechanisms maintaining CT.

When considering the role of psychological factors in the presence of CT, a trend emerged whereby people with CT appeared to fall in a ‘subclinical’ region where they were frequently worse than HC, but not as severe as clinical controls. Furthermore, people with CT who had co-morbid psychological diagnoses reported a greater impact of their tinnitus compared to people with no co-morbid diagnoses. Importantly, the evidence presented here indicates that further investigations of the role of psychological functioning in CT may elucidate specific psychological mechanisms maintaining the presence and/or impact of CT. In turn, this may inform adaptations to optimise and improve the efficacy of current psychological and psychopharmaceutical approaches to the management of CT.

Overall, we found support for impaired psychological functioning in people with chronic tinnitus compared to people without chronic tinnitus, suggesting psychological functioning may contribute to the ongoing awareness of the tinnitus sensation in this population. We propose that a failure in higher-order cognitive control processes responsible for directing attention and working memory resources may underpin some of the heterogeneity and inconsistencies in findings relating to sub-types of memory and attention. Therefore further interrogation of this overarching system is critical to understanding the role of cognition in the presence of CT. In addition, we found evidence of reduced emotional wellbeing, particularly depression and anxiety, which is thought to be symptomatic of neurocognitive network dysfunction, particularly the autobiographical memory network and cognitive control network, with flow on effects for the salience and affective networks, and hypothalamic-pituitary axis. As such, we suggest the neurocognitive networks associated with cognitive control and emotion regulation should be investigated as potential mechanisms facilitating the presence of CT and the severity of its impact.

4.1. Limitations and future research suggestions

4.1.1. Cultural considerations

A substantial portion of research in this area has been conducted in countries where English is not the native language (e.g., Sweden and Germany), and as such, we acknowledge there may be works relevant to this review that have been published in other languages and therefore

excluded. In addition, we note limitations in the cultural diversity of publications included in the present review where the Australasian, Pacific Island, African, Indian, Middle-Eastern and Asian cultures among others, are under-represented (see Fig. 2). There may be cultural differences in the interpretation of the tinnitus sound and thus its impact and perception as a health condition. For example, the tinnitus sensation is interpreted as the loss of an individual's soul in Cambodia (Hinton, Chhean, Pich, Hofmann, & Barlow, 2006). As such, investigations of cultural perspectives in future work and the implications of this for psychological mechanisms of CT are an important consideration moving forward. A greater representation of other cultures' interpretation of the tinnitus sensation may be informative, particularly around the concept of illness representations and coping styles.

4.1.2. Recruitment populations

Reporting information regarding recruitment sources is also recommended in addition to study designs incorporating a range of recruitment strategies to better capture the heterogeneity of CT. In particular, research comparing people with CT to both HC populations and vulnerable clinical populations (e.g., populations with audiological or psychological conditions, sensory sensitivities, or chronically ill health) will help elucidate the nuances of group differences in psychological functioning. While sub-group comparisons within CT populations (i.e., comparing individuals high and low in severity of its impact) may shed light on the role of psychological functioning in the impact of CT, we note that most studies classifying individuals into high and low severity do so by using the mid-point of impact scales. This technique may not capture any naturally occurring clusters within the broader CT population, as it assumes a bimodal distribution. However, a positively skewed distribution is generally reported with most people falling in the low-mid impact range on scales of impact, and less people in the extreme or catastrophic impact tail (e.g., McCombe, Baguley, Coles, McKenna, McKinney, and Windle-Taylor, 2001). Therefore, to validate current methods for comparing people with high and low ratings of tinnitus impact; we recommend investigations of the population distribution (community and clinical) and the use of data-driven methods to determine if there is a spectrum of tinnitus impact, or if there are distinctive clusters or phenotypes.

4.1.3. Tinnitus characterisation

Recommendations for future research also include the use of gold-standard tinnitus impact measures to capture the impact and severity of tinnitus, and the inclusion of duration information capturing both the duration of tinnitus awareness (e.g. > 3 months), and the frequency of awareness (e.g. most of the time), power analyses and effect sizes. This information will help to characterise tinnitus populations for future comparisons between studies, which is particularly important in light of some discrepant findings within specific domains. Given the findings of this review, the inclusion of standardised measures to assess the emotional wellbeing of individuals with tinnitus is recommended for routine use in clinical practice and research studies to facilitate identification and management of potential co-morbid psychological symptoms in patient formulations and research findings.

4.1.4. Hearing health

A commonly proposed confound in CT research is the potential role of hearing health. This is because altered hearing ability (i.e. hyperacusis or hearing loss) may independently influence auditory system functioning, thus potentially masking or enhancing any auditory effects solely related to tinnitus (Adjamian et al., 2009). This viewpoint largely reflects proposed mechanisms of the generation of the tinnitus sound related to peripheral or central auditory system damage as the mechanism of tinnitus perception (see Section 1.1). While some research indicates a relationship between uncorrected hearing impairments and both cognitive functioning and mood, this work is largely on older populations, with moderate-severe hearing loss for whom tinnitus is not

a primary clinical complaint (Chang-Quan, Bi-Rong, Zhen-Chan, Ji-Rong, & Qing-Xiu, 2010; Wayne & Johnsrude, 2015). In addition, the use of hearing aids has been shown to ameliorate cognitive difficulties associated with hearing loss (Amieva, Ouvrard, Giulioli, Meillon, Rullier, and Dartigues, 2015; Qian, Wattamwar, Caruana, Otter, Leskowitz, Siedlecki, et al., 2016). As such, understanding the relationships between ageing, hearing ability, cognitive functioning and emotional wellbeing in people with CT is an area requiring future research.

As an initial step, understanding the relationships between these factors in people without tinnitus may help inform the role of hearing in tinnitus research, particularly by identifying the point at which hearing loss may pose a significant risk to psychological functioning, and what mechanisms underpin this relationship. Research investigating the interaction between these factors in people with and without CT across a range of hearing abilities may also help to determine if hearing ability is a critical factor in the maintenance of CT, or if it is a by-product of the effects of age, mood or cognition. In other words, is the potential contribution of hearing ability to the maintenance of CT mediated by factors known to be related to both hearing ability and CT perception (e.g. depressive symptoms, cognitive function). Measurement of hearing health from both an audiological perspective (e.g. hearing thresholds) and a psychosocial perspective (e.g. associated disability) will be important for unpacking these relationships.

4.1.5. Future directions

Importantly, while this review has provided a summary of evidence that has shown support for the existence of relationships between CT and impaired psychological functioning, we have also highlighted the need to determine the complexities of the relationships between these factors. Identifying factors that may moderate, mediate or otherwise impact the relationship between psychological factors and the presence and impact of CT is now necessary to untangle how specific processes (e.g. depressive symptoms) may be driving CT or potentially exacerbating other aspects of emotional wellbeing or cognitive functioning. For example, given reduced cognitive functioning has been associated with both anxiety (Eysenck, Derakshan, Santos, & Calvo, 2007) and depression (Gotlib & Joormann, 2010) expanding our understanding of the interactions between cognitive and emotional processes in CT is an exciting new frontier for investigating the mechanisms of CT. Longitudinal observational or cross-sectional research designs may help support the emerging research on the predictors of tinnitus impact, and for determining whether there is a bi-directional relationship between emotional wellbeing, or cognitive functioning, and the presence and impact of CT. For example, a population study using a longitudinal design identified a role of both hearing loss and depressive symptoms in predicting the prevalence of tinnitus, with a particular role for depression in the severity of tinnitus (Hébert et al., 2012). Extending this work to assess additional psychological factors, particularly cognitive functioning, and applying these methods within acute and chronic tinnitus populations will be important for establishing these relationships. Furthermore, advances in neuroimaging and neuroscience techniques offer the opportunity to unpack the neurobiological mechanisms that may underpin potential psychological mechanisms in CT. In particular, stable, large-scale neural networks associated with the broad array of psychological factors potentially involved in CT, particularly cognitive and emotional control, may provide a useful basis for future investigations as these processes and their associated neural networks have been implicated in a range of psychological and neurological conditions (Menon, 2011).

5. Conclusion

The present review has established that psychological factors, including aspects of cognitive functioning and emotional wellbeing, are integral to the presence and impact of CT. The broad array of

psychological functions implicated here suggests the involvement and/or disruption of ordinarily stable large-scale neural networks in the persistence and pervasiveness of this chronic health condition. A crucial next step however, is the systematic exploration of the complexities of the relationships between psychological factors, including anxiety, attention, bodily symptoms (somatisation), depression, and coping strategies, to advance our understanding of the psychological mechanisms underpinning CT.

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Contributions

All authors contributed to the study concept. KT conducted the literature searches and statistical analyses under the supervision of SW. KT and SW wrote the manuscript. All authors approved the final version of the manuscript for submission.

Conflict of interest

All authors declare that they have no conflicts of interest.

Appendix A

Table A.1

A detailed summary of studies investigating psychological functioning in people with chronic tinnitus ($n = 64$).

Study	Focus	Sample (n, % male)	Source	Tinnitus characteristics	Measures	Outcomes for people with chronic tinnitus
Andersson (1996), Sweden	Severity	CT (30)	Clinical	Duration: 8.8 (8.48) yrs. Severity: TEQ 70.3 (27.44)	LOT	Severity associated with decreased optimism.
^a Andersson and Vretblad (2000), Sweden	Severity	CT (146, 47%)	Clinical	Duration: 10.5 (12.5) yrs. Severity: TRQ 34.5 (23.9)	ASI	Severity associated with anxiety sensitivity. Severity predicted by anxiety sensitivity and masking.
^a Andersson et al. (2000), Sweden	Presence	CT (23, NS) HC (23, NS)	CT Clinical HC Community	Duration: 6.3 (4.1) yrs. Severity: S-TQ 70.3 (22.8)	Emotional stroop test, STAI-S, BDI, vocabulary test	Increased anxiety and depression, but impaired cognitive performance.
^a Andersson et al. (2002), Sweden	Presence	CT (20, 50%) HC (20, 50%)	NS	Duration: 7.9 (10.6) yrs. Severity: TRQ 36.3 (18.6)	D-ST, BAI, BDI	Increased anxiety and depression, but impaired cognitive performance.
^a Andersson et al. (2003), Sweden	Presence	CT (19, 37%) HC (19, 32%)	CT Clinical HC Community	Duration: 8.4 (8.8) yrs. Severity: TRQ 37.3 (21.6)	AMT, BAI, BDI, COWAT	Increased anxiety and depression, similar verbal fluency, impaired autobiographical memory.
Andersson et al. (2004), Sweden	Presence	CT (48, 52%)	Community, hearing association	Duration: 6.1 (5.5) yrs. Severity: TRQ 40.5 (22.9)	HADS, ASI, CIDI-SF	High prevalence of potential psychiatric disturbance in CT.
^a Andersson et al. (2005), Sweden	Presence	CT (104, 44%) HC (21, 52%)	CT Clinical HC Community	Duration: 10.1 (11.0) yrs. Severity: TRQ 24.2 (18.9)	HADS, emotional stroop test	Faster responses to tinnitus-words. (i.e., information processing bias in CT).
^a Andersson et al. (2009), Sweden	Presence	CT (18, 44%) HC (18, NS)	CT Clinical HC NS	Duration: 5.6 (7.0) yrs. Severity: TRQ 32.3 (21.9)	CFQ, HADS, serial recall task, SRB:1	Increased subjective cognitive difficulties, anxiety and depression, similar verbal ability, serial recall, and background sound interference.
^a Araneda et al. (2015), Belgium	Both	CT (17, 35%) HC (17, 35%)	CT Clinical HC Community	Duration: ≥ 6 mon Severity: THI (mean ns)	BDI, SDS, BAI, VAS Stroop test, stimulus detection	Similar anxiety and depression scores, but impaired cognitive performance on most tests. Severity was not associated with cognitive performance, though tinnitus annoyance was.
Bartels et al. (2010), Netherlands	Severity	CT + Type D (94, 73%) CT (171, 68%)	Clinical	CT + Type D Severity: TRQ: 63.4 (15.5); CT: Severity: TRQ: 45.6 (21.9) All: Duration ≥ 3 mon	DS14, HADS, MQ, SF36	Greater severity and lower emotional wellbeing in CT-Type D (distressed) personality. Anxiety and depression mediated the relationship between Type-D personality and tinnitus severity.

Bauch et al. (2003), USA	Severity	CT (53, 68%)	Clinical	Duration: 5 ^c (range 5 weeks – 57 yrs) Severity: THI 49% no handicap, 26% mild, 11% moderate, 13% severe	SCL-90-R	Severity associated with greater global distress. A subset of high-distress CT patients identified compared to normative data.
Bayar et al. (2002), Turkey	Presence	CT (28, 57%) HC (28, 57%)	Clinical	Duration: 1–20 yrs. Severity: ATA questionnaire adaptation	MMPI	Psychoasthenia higher in CT, in addition to greater hypochondriasis, hysteria, schizophrenia and introversion among females with CT.
^a *Budd and Pugh (1995), Wales	Severity	CT (109, 70%)	Clinical	Duration: 6.8 (7.8) yrs. Severity: in-house measure	BDI, LCB, STAI-S	Severity associated with greater external locus of control, depression and anxiety. Anxiety and depression mediate the association between severity and locus of control.
Caldirola et al. (2016), Italy	Severity	CT (54, 54%)	Clinical	Duration: 55.96 (62.64) months Severity: THI 44.76 (26.66)	PSWQ, SAD, STAI-S	Severity predicted by greater worry attitudes.
Cima et al. (2011), Netherlands	Severity	CT (61, 39%)	Clinical	Duration: 2.6 (0.9) yrs. Severity: TQ 50 (16.8)	HADS, SF36, TCS, FTQ, TVAQ	Severity associated with quality of life, catastrophising thoughts, vigilance, and fears about tinnitus. Tinnitus fears mediated the relationship between catastrophising thoughts and quality of life.
^a *Crocetti et al. (2009) Italy	Severity	CT (108, 67%)	Clinical	Duration: ≥ 6 mon Severity: THI 39.8 (23.5)	BDI, STAI-T, VAS	Severity associated with anxiety and depression.
Das et al. (2012), USA	Severity	CT-low severity (55, 66%) CT-high Severity (37, 54%)	Clinical	CT-low severity Duration: 13.2 (14.0) yrs. Severity: THI 18 (7) CT-high Severity Duration: 14.1 (13.0) yrs. Severity: THI 42 (12)	BST, Stroop, PASAT, AQT, PHQ9, Whiteley-7	Severity associated with emotional wellbeing, and with cognition for CT-high severity. Severity predicted by cognitive performance and emotional wellbeing.
Fioretti et al. (2013), Italy	Severity	CT (37, 49%)	NS	Duration: ≥ 3 mon Severity: THI 37.9 (22.2)	TSCH	Increased severity in participants with sound sensitivity and sleep for a high tinnitus severity subgroup.
^a *Folmer et al. (2008), USA	Severity	CT (196, 32%)	Clinical	Duration: 7.1 (10.5) yrs. Severity: TSI 40.4 (9.9)	STAI, MOCI, BDI	Severity associated with increased obsessive-compulsive symptoms, depression and anxiety. CT + high obsessive-compulsive symptoms had high levels of severity, depression and anxiety than CT + low obsessive-compulsive symptoms.
Goldberg et al. (2017), USA	Severity	CT (40, 75%)	Clinical, support groups	Duration: ≥ 6 mon, 15 ^c yrs. (range 0.58–50 yr) Severity: TFI 36.6 (21.3)	Single question on stress	Stress and tinnitus severity vary over time together.
Gomaa et al. (2014), Egypt	Severity	CT (100, 40%)	Clinical	Duration: 1–60 months Severity: VAS 28% mild, 54% moderate, 18% severe	DASS	Severe CT associated with greater stress. No association between severity and depression or anxiety.
Granjerio et al. (2013), Brazil	Both	CT (68, 46%) HC (46, 28%)	Clinical	Duration: 5.95 (6.7) yrs. Severity: THI 25% very mild, 38% mild, 25% moderate, 12% severe	BDI, BAI	Greater anxiety and depression in CT. Increased severity associated with more frequent anxiety and depression.
^a *Halford and Anderson (1991), UK	Severity	CT (112, 39%)	Support group	Duration: 82% > 4 yrs. Severity: STSS (mean NS)	STAI-T, DTQ	Severity associated with anxiety and depression.
^a *Hébert and Carrier (2007), Canada	Both	CT (51, 59%) HC (51, 47%)	CT Support groups, community HC Community	Duration: 14.0 (12.2) yrs. Severity: TRQ 17.39 (18.0)	PSQI, BDI-II, HQ	Worse sleep, increased depression and hyperacusis. Severity was associated with sleep quality, depression and hyperacusis.

^a *Heeren et al. (2014), Belgium	Both	CT (20, 50%) HC (20, 50%)	CT Support group HC Community	Duration: 10.9 (13.8) yrs. Severity: TPIQ-everyday life 29.10 (17.6)	ANT, MMSE, STAI-T, BDI	Similar anxiety and depression scores, but slower reaction times (especially for executive control). Severity subcomponents, coping and duration, associated with executive control impairment.
Hesser et al. (2009) Sweden	Intrusion	CT (35, 60%)	Clinical	Duration: 7.8 (8.2) yrs. Severity (THI and TRQ) reported for task groups	HADS, ISI, D-ST	Controlling background sounds increased tinnitus interference and decreased task performance (i.e., controlling background sound increases severity).
^a *Hesser et al. (2015), Sweden	Severity	CT (362, 52%)	Clinical	Duration: 12.5 (9.4) yrs. Severity: THI 39.2 (22.2)	TAQ, HADS	Severity associated with acceptance, anxiety and depression. Acceptance mediated the relationship between tinnitus loudness and severity.
Hoekstra et al. (2014), The Netherlands	Severity	CT (309, 67%)	Clinical	Duration: 7 yrs. (range 2 mon–82 yrs) Severity: THI 45 (23); TQ 40 (17)	SCL-90-R,	Presence of depression and/or anxiety was associated with, and predictive of, increased severity. Presence of pain and somatic complaints were associated with, and predictive of, increased severity.
^a Kehrle et al., (2015), Brazil	Both	CT (84, 45%) HC (47, 47%)	CT Clinical HC NS	Duration: 5.58 (5.91) yrs. Severity: THI 27.4% no handicap, 35.7% mild, 21.4% moderate, 15.5% severe	BDI, BAI	Increased report of depression and anxiety symptoms in the CT group. Higher levels of depression and anxiety observed in those with more severe CT.
Kim (2015), South Korea	Severity	CT (100, 48%)	Clinical	Duration: > 3 mon Severity: mean NS (THI)	STAI-S, – T, BDI, PSQI, SPAQ	Increased severity in individuals with Seasonal Affective Disorder and CT.
Kirsch et al. (1989), USA	Both	CT (77, 42%) HC (65, 28%) MC (34, 38%)	CT Clinical HC NS MC Clinical	Duration: means ranged from 3.4–7.9 yrs. Severity: VAS (annoyance) 44.6 (24.3) in high-copers, 73.7 (24.3) in low-copers	STAI-S, STAI-T, BDI, LES, PSC	Severity associated with coping. CT + low coping had worse depression, anxiety and somatic symptoms compared to CT + High coping. CT + low coping similar to MC for depression and anxiety, but lower somatic symptoms.
Liu et al. (2015), USA	Severity	CT (94, 99%)	Veterans Clinic	Duration: ≥ 1 yr Severity: THI 57 (23.5)	ESS	Increased rates of PTSD, anxiety and depression. High-severity associated with greater incidence of PTSD, anxiety and sleep disorders.
^a *Mannarelli et al. (2017), Italy	Presence	CT (20, 40%) HC (20, 40%)	CT Clinical HC Community, relatives	Duration: 22.3 (14.2) months Severity: THI 29.5 (14.5)	BDI, STAI–S, STAI-T, MMSE	Similar cognitive functioning, depression and state anxiety scores, but increased trait anxiety in CT.
Marciano et al. (2003), Italy	Presence	CT (75, 60%)	Clinical	Duration: ≥ 6 mon Severity: in-house measure	MMPI, MINI	Compared to normative data, a large proportion of CT had personality alterations, primarily hypochondria, hysteria and depression.
Meric et al. (1998), France	Both	CT (281, 59%)	Clinical	Duration: 5.0 yrs. (1 mon–41 yrs) Severity: THQ 37.2 ^c (SIQ 38.5); STSS 10 ^c (SIQ 1.5); TRQ 31.5 ^c (SIQ 19)	Mini-MMPI	Similar personality profile to norms. Severity associated with pathological personality traits.
^a *Meyer et al. (2017), Switzerland	Severity	CT (45, 76%)	NS	Duration: 82.71 (124.03) months Severity: TQ 38 (13.14)	BDI	Severity associated with depressive symptoms.
^a *Milerova et al. (2013), Germany	Severity	CT (317, 71%)	Clinical	Duration: ≥ 6 mon Severity: THI and TQ (means NS)	SCL-90-R	Severity predicted by depression, hostility and somatisation.

^a *Moring et al. (2015), USA	Severity	CT (371, 68%)	Support group	Duration: 176.04 (176.30) months Severity: THI 70.32 (25.17)	AAQ, ASI	Severity associated with anxiety sensitivity and acceptance. Severity predicted anxiety sensitivity, though this was mediated by acceptance.
Newman et al. (1997), USA	Severity	CT-low self attenders (32, 78%) CT-high self attenders (19, 35%)	Clinical	CT-low self attenders Duration: 7.8 (8.2) yrs. Severity: TRQ 11.9 (12.5); THQ 19.3 (14.0) CT-high self attenders Duration: 8.7 (9.7) yrs. Severity: TRQ 35.1 (26.7); THQ 45.1 (23.8)	SFSC, PSCS, MSPQ, SCL-90-R, BDI	Greater tinnitus severity and depression in CT-high self-attenders than CT-low attenders.
Oishi et al. (2011) Japan	Severity	CT (285, 48%)	Clinical	Duration: 4.3 (6.6) yrs. Severity: THI 56 (24)	SDS, STAI–S, STAI-T	Severity predicted by depression, anxiety and high frequency hearing loss.
^a *Ooms et al. (2011a) Belgium	Severity	CT (136, 35%)	Clinical	Duration: 2.2 (3.9) yrs. Severity: THI 44.12 (22.72)	BDI-II	Severity associated with depression and predicted by somatic depressive symptoms.
^a *Ooms et al. (2012) Belgium	Severity	CT (71, 63%)	Clinical	Duration: 3.6 (4.9) yrs. Severity: THI 43.36 (22.34)	STAI-S, STAI-T, somatic anxiety ^d	Severity associated with anxiety.
^a *Ooms et al. (2013) Belgium	Severity	CT (67, 63%)	Clinical	Duration: 3.7 (4.9) yrs. Severity: THI 43.88 (21.86)	STAI-T, APT	Severity associated with anxiety and disrupted automatic processing.
Pajor (2013), Poland	Both	CT (100, 44%)	Clinical	Duration: 2.4 (3.1) yrs. Severity: VAS 60% mild, 37% moderate, 3% severe	HADS, BDI, TMT, MMSE	CT had increased anxiety and cognitive dysfunction than normative data. Severity associated with depression. No association with cognitive functioning or anxiety.
Pierce et al. (2012) USA	Presence	CT (14, 71%)	NS	Duration: 7.0 ^c (0.5–17.9) yrs. Severity: THI 51 ^c (38–76)	COWAT, CVLT	Impaired immediate recall and learning rate, but similar verbal fluency and short and long recall.
^a *Rossiter et al. (2006) Australia	Presence	CT (19, 84%) HC (19, 68%)	Support group, word of mouth	Duration: ≥ 3 mon Severity: TRQ 36.4 (22.8)	STAI, CFQ, NART, RST, divided attention task	Impaired performance on working memory and attention tasks.
^a *Rutter and Stein (1999), UK	Both	CT (91, 59%) HL (71, 41%) ENT (78, 50%)	CT Clinical HL Clinical ENT Clinical	Duration: 4.4 (0.8) yrs. Severity: S-TQ (subscale means only)	HADS, EPQ	Increased anxiety, depression and neuroticism scores than HL, lower extraversion scores than ENT. Severity associated with emotional wellbeing, extraversion and neuroticism.
Sahin et al. (2016), Turkey	Both	CT (30, 53%) HC (30, 43%)	NS	Duration: ≥ 6 months Severity: THI 28.1 (19.8)	SDQ-20	Increased somatoform disorder symptoms in CT. Severity associated with somatic symptoms.
^a *Stevens et al. (2007), Australia	Both	CT (11, 64%) HC (11, 45%)	CT Clinical, community HC Community	Duration: ≥ 2 yrs. Severity: TQ 47.6 (24.5)	NART, STAI–S, STAI-T BDI-II, Stroop, divided attention task	Impaired performance on attention tasks. Severity associated with attention task performance.
Stobik et al. (2005), Germany	Severity	CT-low severity (28) CT-high Severity (25) All: 77% male	Clinical	CT-low severity Severity: TQ 36.4 (27.9) CT-high Severity Severity: TQ 60.7 (7.8) All: Duration ≥ 6 mon	SCL-90-R, FKV, IIP-D, BSS	Greater impairment in emotional wellbeing, subjective concentration and greater use of depressive coping strategies in CT-high severity.
^a *Stuerz et al. (2009), Austria	Both	CT (65, 57%)	Support groups	Duration: 6 mon-2 yrs. Severity: TQ 41.3 (15.5)	BDI, FKB-20, FbeK	Lower body image ratings than norms. High-severity subgroup had greater insecurity than low-severity subgroup.
^a *Temugan et al. (2016), Turkey	Severity	CT (44, 41%)	Clinical	Duration: ≥ 3 mon Severity: THI 28.04 (20.03)	BDI	Severity was not associated with depression.

^a *Trevis et al. (2016a), Australia	Both	CT (26, 58%) HC (26, 46%)	Community	Duration: 13.50 (14.08) Severity: THI (mean NS)	n-back, SST, DST, BDI, STAI-T, CFQ	Reduced cognitive and inhibitory control in CT, similar working memory. Greater depression and cognitive complaints in CT, similar anxiety. CT presence predicted by cognitive control and depressive symptoms. Severity associated with depression.
^a *Trevis et al. (2016b), Australia	Severity	CT (81, 43%)	Community	Duration: 14.68 95% CI [11.70, 17.66] Severity: THI 26.32 95% CI [21.79, 30.85]	BDI-II, STAI-T, IAS, OBQ-44, WAYS	Severity associated with depression, anxiety, illness attitudes, and obsessive-compulsive symptoms. Depression mediated the relationship between severity and anxiety.
Unterrainer et al. (2003), Germany	Severity	CT (149, 52%)	Clinical	Duration: 5.9 (8.2) yrs. Severity: THI-12 (mean NS)	ADS, CES-D, LoC	Severity predicted by depression, tinnitus loudness, and internal locus of control.
^a *Waechter and Brännström (2015), Sweden	Presence	CT (20, 45%) HC (20, 45%)	CT Clinical, community HC Clinical, community	Duration: 12.9 yrs. Severity: TQ 40.1 (13.5)	Stroop, HADS	Similar anxiety, depression and cognitive performance results.
^a *Wallhäusser-Franke et al. (2012) Germany	Severity	CT (4705, 29%) ^b	Support group	Duration: 84% > 5 yrs. Severity: MTQ 37.6% mild, 49% intermediate, 13.4% severe	PHQ9, GAD-7, PHQ15	Severity associated with poor emotional wellbeing. Severity predicted by depression, anxiety, sleep problems and permanent awareness of tinnitus.
Wallhäusser-Franke et al. (2014) Germany	Severity	CT (4705, 58%) ^b	Support group	Duration: 84% > 5 yrs. (2% unknown) Severity: MTQ 10.4 (6.5) (0.9% missing)	RS13, PHQ9, GAD-7, PHQ15	Severity associated with depression, anxiety, somatic symptoms and resilience. Emotional wellbeing mediated the relationship between resilience and severity.
Weidt et al. (2016), Switzerland	Both	CT (208, 65%)	Clinical	Duration: 5.49 (8) yrs. Severity: THI 44.3(23)	BDI, WHO-QoL-Brief	Increased depression and reduced quality of life in CT compared to normative data. High-severity patients reported worse quality of life and greater depression than low-severity patients.
Westin et al. (2008), Sweden	Intrusion	CT (47, 49%)	Clinical	Duration: 6.3 (8.2) yrs. Severity: THI means reported for task groups	HADS, imagery attention task (3 groups)	Accepting the tinnitus sound increased task engagement, decreasing tinnitus intrusiveness.
^a *Zeman et al. (2014), Germany	Severity	CT (1274, 66%)	Tinnitus Research Initiative database	Duration: 5.0 ^c (IQR: 1.6–11.9) yrs. Severity: THI 46 ^c (IQR: 30–66)	BDI, WHO-QoL Brief	Severity predicted depression and quality of life.
^a *Zirke et al. (2013a) Germany	Severity	CT (100, 45%)	Clinical	Duration: ≥ 3 mon Severity: TQ 35 (16.1)	CIDI, HADS, GAD-7	Severity associated with anxiety and depression.
^a *Zirke et al. (2013b) Germany	Both	CT (300, 51%) MC (595, 28%)	CT Clinical MC Clinical	Duration: ≥ 3 mon Severity: TQ 75% high severity (scores < 47), 25% low severity (scores ≥ 47)	BMQ, GPCI, PSQ, SOC-L9	Greater emotional wellbeing than medical controls. High severity subgroup had decreased emotional wellbeing, similar to medical controls, than low-severity subgroup.
^a *Zoger et al. (2006), Sweden	Severity	CT (144, 60%)	Clinical (High-risk)	Duration: 2 ^c (IQR 1–5) yrs. Severity: TSQ mean NS	SCID, HADS, CPRS	Severity associated with presence of depression and anxiety disorders, and with the severity of symptoms.

Note: NS = not stated, IQR = Interquartile Range, SIQ = Semi-interquartile range, PTA = Pure Tone Averages.

Groups: CT = chronic tinnitus, DC = depressed control, ENT = ear, nose and throat clinical outpatients, HC = healthy control, HL = hearing loss control, MC = medical control.

Tinnitus Severity measures: ATA = American Tinnitus Association, MTQ = Mini Tinnitus Questionnaire, STSS = Subjective Tinnitus Severity Scale, S-TQ = Short Tinnitus Questionnaire, TEQ = Tinnitus Effect Questionnaire, TFI = Tinnitus Functional Index, THI = Tinnitus Handicap Inventory, THI-12 = brief version of the THI, THQ = Tinnitus Handicap Questionnaire, TPIQ = Tinnitus Psychological Impact Questionnaire, TQ = Tinnitus Questionnaire, TRQ = Tinnitus Reaction Questionnaire, TSI = Tinnitus Severity Index, TSQ = Tinnitus Severity Questionnaire.

Cognitive measures: AMT = Autobiographical Memory Test, ANT = Attention Network Test, APT = Affective Priming Task, AQT = A Quick Test of Cognitive Speed, BST = Brain Speed Test, COWAT = Controlled Oral Word Association Test, CVLT = California Verbal Learning Test, D-ST = Digit-Symbol test, DST = Digit Span Task, FTT = Future thinking test, MMSE = Mini Mental State Exam, NART = National Adult Reading Test, PASAT = Paced Auditory Serial Addition Test, RST = Reading Span Test, SRB:1 = Synonym verbal ability test, SST = Stop-Signal Task.

Emotional wellbeing measures: AAQ = Acceptance and Action Questionnaire, ADS = Allgemeine Depression Skala (General Depression Scale, Hautzinger and Bailer), AES = Assessing Emotions Scale, ASI = Anxiety Sensitivity Index, BDI = Beck Depression Inventory, BMQ = Berlin Mood Questionnaire, BSS = Impairment Severity Score, CES-D = Center of Epidemiological Studies – Depression scale, CFQ = Cognitive Failures Questionnaire, CIDI = Composite International Diagnostic Interview, CIDI-SF = Composite International Diagnostic

Interview Short Form, CPRS = Comprehensive Psychopathological Rating Scale, DASS = Depression, Anxiety and Stress Scale, DS14 = 14-item Type D Scale, DTQ = Depressive Tendency Questionnaire, EPQ = Eysenck Personality Questionnaire, ESS = Epworth Sleepiness Scale, FbE-20 = Questionnaire for assessing one's own body, FKB-20 = Body Image Questionnaire, FKV = Disorder Coping Questionnaire, FTQ = Fear of Tinnitus Questionnaire, GAD-7 = General Anxiety Disorder-7, GHQ-12 = General Health Questionnaire-12, GPCI = Giessen Physical Complaints Inventory, HADS = Hospital Anxiety and Depression Scale, HQ = Hyperacusis Questionnaire, IAS = Illness Attitudes Scale, IIP-D = Inventory of Interpersonal Problems, IPQ-R Illness Perceptions Questionnaire Revised, ISI = Insomnia Severity Index, LCB = Locus of Control of Behaviour, LES = Life Events Scale, LoC = German Locus of Control Instrument by Lohaus and Schmitt, LOT = Life Orientation Test, MMPI = Minnesota Multiphasic Personality Inventory, MOCI = Maudsley Obsessional-Compulsive Inventory, MINI = Mini International Neuropsychiatry Interview, MQ = Maastricht Questionnaire (vital exhaustion), MSPQ = Modified Somatic Perception Questionnaire, NHP = Nottingham Health Profile, OBQ-44 = Obsessive Beliefs Questionnaire, PHQ9 = Patient Health Questionnaire – depression, PHQ15 = Patient Health Questionnaire somatic symptoms, PSC = Psychosomatic Symptom Checklist, PSCS = Private Self-Consciousness Scale, PSQ = Perceived Stress Questionnaire, PSQI = Pittsburgh Sleep Quality Index, PSWQ = Penn State Worry Questionnaire, RS13 = Resilience Scale short version, SAD = Scala di Autovalutazione della Depressione, SCID = Structured Clinical Interview for DSM-III-R, SCL-90-R = Symptom Check List-Revised, SDQ-20 = Somatoform Disorder Questionnaire, SDS = Self-rating Depression Scale, SF36 = Short Form 36, SFSC = Self-Focus Sentence Completion Test, SOC-19 = Leipzig Short Scale for Recording the Sense of Coherence, SPAQ = Seasonal Pattern Assessment Questionnaire, STAI-S = State Trait Anxiety Inventory-State form, STAI-T = State Trait Anxiety Inventory-Trait form, TAQ = Tinnitus Acceptance Questionnaire, TCS = Tinnitus Catastrophising Scale, TEQ = Tinnitus Experience Questionnaire, TRSS = Tinnitus Related Self Statement Scale, TSCH = Tinnitus Sample Case History, TVAQ = Tinnitus Vigilance and Awareness Questionnaire, VAS = Visual Analogue Scale, WAYS = Ways of Coping Questionnaire, WHO-QoL = World Health Organisation-Quality of Life Questionnaire.

^a Included in meta-analyses

^b Same sample

^c Median value reported

^d In-house measure

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