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Research report

EEG oscillatory power dissociates between distress- and depression-related psychopathology in subjective tinnitus

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ABSTRACT

Recent research has used source estimation approaches to identify spatially distinct neural configurations in individuals with chronic, subjective tinnitus (TI). The results of these studies are often heterogeneous, a fact which may be partly explained by an inherent heterogeneity in the TI population and partly by the applied EEG data analysis procedure and EEG hardware.

Hence this study was performed to re-enact a formerly published study (Joos et al., 2012) to better understand the reason for differences and overlap between studies from different labs. We re-investigated the relationship between neural oscillations and behavioral measurements of affective states in TI, namely depression and tinnitus-related distress by recruiting 45 TI who underwent resting-state EEG. Comprehensive psychopathological (depression and tinnitus-related distress scores) and psychometric data (including other tinnitus characteristics) were gathered. A principal component analysis (PCA) was performed to unveil independent factors that predict distinct aspects of tinnitus-related pathology. Furthermore, we correlated EEG power changes in the standard frequency bands with the behavioral scores for both the whole-brain level and, as a post hoc approach, for selected regions of interest (ROI) based on sLORETA. Behavioral data revealed significant relationships between measurements of depression and tinnitus-related distress. Notably, no significant results were observed for the depressive scores and modulations of the EEG signal. However, akin to the former study we evidenced a significant relationship between a power increase in the β-bands and tinnitus-related distress.

In conclusion, it has emerged that depression and tinnitus-related distress, even though they are assumed not to be completely independent, manifest in distinct neural configurations.

1. Introduction

Tinnitus is the notion of a subjective, auditory phantom percept of chronic high-pitched noise, sound or ringing, which lacks any objective, external sound source (Eggermont and Roberts, 2004). In the steadily aging populations of Western industrialized countries, the number of individuals who suffer from tinnitus is immense. Cederroth and colleagues (Cederroth et al., 2013) estimate that it affects approximately 50 million people in the US and 70 million people (roughly 10% of the population) in the European Union. At present, it is widely accepted that tinnitus should not be considered as a sole dysfunction of the outer or inner ear, even though tinnitus is normally preceded and accompanied by transient to severe hearing loss (Henry and Meikle, 2000; Roberts et al., 2012). Rather, it has been suggested that subjective tinnitus is engendered by a perplexing network that involves both the cochlea and the auditory pathway, but is primarily generated, maintained and chronically accommodated by the (human) brain (Adjamian et al., 2009; De Ridder et al., 2011a; Elgoyhen et al., 2015; Rauschecker et al., 2015; Jastreboff, 1990; Vanneste and De Ridder, 2012).

No matter which circumstances may account causally for the generation of tinnitus, the reality of it is highly subjective in nature

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and, for this reason, it is not considered to be a physical disease but rather a heterogeneous diffuse phenomenon that lacks a clearly defined neurological pathogenesis (Sedley et al., 2012). Thus, it is unsurprising that several, partly conflicting, neurobiological models exist, each sketching the complex interplay between multiple cortical and subcortical human brain areas underlying the subjective experience of chronic tinnitus (De Ridder et al., 2014; De Ridder et al., 2011a; Llinas et al., 1999; Llinas et al., 2005; Rauschecker et al., 2010; Sedley et al., 2012). These models are partly based on observations provided by functional imaging studies and partly on evidence gathered from electro- and/or magnetencephalographic (M/EEG) studies. The numerous, specific constraints in data acquisition and analysis inherent to these methods may have worsened the present situation even further (Adjamian, 2014). While hemodynamic-based neuroimaging techniques lack a reasonable temporal resolution, neuroelectrical-based M/EEG are less advantageous in the identification of neural sources that reside in widely distributed cortical and deeply encased subcortical areas. To date, no ideal solution has been offered with which to amalgamate the advantages of the two different approaches into one setting. However, we favor neurophysiological M/EEG techniques in the context of tinnitus research because these approaches are not accompanied by bothersome gradient noise and hence are more comfortable for TI, who often show symptoms of hyperacusis. Further, comprehensive leaps have been made to improve the spatial resolution of M/EEG through the development of innovative source estimation approaches (Adjamian, 2014).

In the realm of M/EEG, spectral power analysis of spontaneous oscillations during the resting-state has been identified as an advantageous tool, because TI have demonstrated deviations from the normal EEG pattern in the activity strength of various frequency bands (for an overview see Adjamian, 2014; Elgoyhen et al., 2015). Resting-state neurophysiological measurements seem ideally suited to investigate the neural correlates of tinnitus because, during data acquisition, participants are in a relaxed and quiet setting without the distractions of external stimulation. However, it should be noted that the outcomes of different studies, which have applied the relatively controlled resting-state condition, exhibit substantial differences in EEG activity in the δ-, θ-, β-, and γ-bands. While it cannot be ruled out that differences in technical and methodological parameters (e.g., recording device, measurement protocol, signal processing, experimental setting) may account for the discrepancies in the results, it is also possible that the psychopathological heterogeneity within the population of TI is the source of these disparities.

At present, it is widely agreed that TI differ considerably in subjective quality and loudness of the perceived tinnitus sound, the presence and degree of hearing-loss, the duration since onset of tinnitus, and age. On the other hand, psychopathological aspects, namely the extent of distress and the presence and influence of clinically relevant comorbidity like depression and anxiety contribute to this heterogeneity. Recent suggestions towards overcoming these challenges include abandoning the established approach, in which TI are compared to healthy controls (CO) (Meyer et al., 2014; Vanneste et al., 2014a). Instead, it has become imperative to search for relationships between psychometric, psychopathological and neural patterns in a sample of TI only. This approach is advisable for several reasons. First, important variables, amongst others the presence of affective disorders and/or hearing loss, have often been ignored in the samples of CO leading to systematic errors being made in the comparison of two groups along only one dimension, that being the presence/absence of chronic tinnitus. Second, the investigation of and concentration on the psychometric, psychopathological and neural profiles of TI only, allows for due attention to be paid to the differences between TI. Along these same lines, Elgoyhen et al. (2015, p. 639) emphasize that "studies with better patient stratification, and controlling for hearing loss, hyperacusis, distress, depression and tinnitus perceptual characteristics are needed". Eventually, this approach will result in a classification of tinnitus subtypes. Third, by using a data-driven PCA approach, the analysis of behavioral data serves as a reliable platform from which to establish relationships between tinnitus-related pathophysiology and changes in EEG frequency bands along the entire power spectrum (Pierzycki et al., 2016; Meyer et al., 2014).

Even supposing that one carefully considers the above mentioned suggestions it is not guaranteed that a simplified study design only including TI will yield replicable results as long as data recording and analysis do not concur with established and standardized procedures. The present study primarily aims at leaping forward into this direction in that it re-enacts former studies while it systematically minimizes conceptual and methodological error sources to enhance comparability between past and present data.

1.1. The present study

The present situation in tinnitus research is unsatisfactory because a number of different studies have used resting-state EEG to identify oscillatory modulations, and have reported either heterogeneous (De Ridder et al., 2011b; Joos et al., 2012; Meyer et al., 2014; Moazami-Goudarzi et al., 2010; Ortmann et al., 2011; Van der Loo et al., 2009; Van der Loo et al., 2011; Vanneste et al., 2010; Vanneste et al., 2014a; Vanneste et al., 2014b; Zobay et al., 2015) or nil results (Pierzycki et al., 2016). To overcome the unsatisfactory inconsistency between tinnitus-related neurophysiological studies (which provide the bases for many tinnitus network models), we believe that it is of the utmost importance to replicate and to confirm previous results as provided by other labs, rather than continuously producing new studies, data, and models that generate more questions than answers. Hence, we decided to tackle one topic by re-enacting a former neurophysiological study (Joos et al., 2012) that addressed the relationship between tinnitus-related distress and depression. For this purposes we compiled a sample of TI with similar psychopathological profiles. Clinically pertinent prevalences of depressive and anxiety disorders were noted consistently in TI populations (Loprinzi et al., 2013; Zöger et al., 2001; Weidt et al., 2016). However, it should be emphasized that tinnitus-related distress must not be automatically equated with the umbrella term depression. We think it is mandatory to propose that tinnitus-related distress aggregates cognitive, somatic and emotional aspects. Both depression and distress are well operationalized and standardized concepts that can be empirically and behaviorally quantified in subjective, chronic tinnitus. Recent approaches using power spectrum analysis have attempted to correlate measured psychopathology of depression and distress with specific changes of oscillations in either distinct or a selection of frequency-bands (De Ridder et al., 2011b; Joos et al., 2012; Song et al., 2015; Van der Loo et al., 2011; Vanneste et al., 2010; Vanneste et al., 2014a; Weisz et al., 2004; Weisz et al., 2005). As these studies suggest, it can be concluded that even high distress may be completely independent from depression (De Ridder et al., 2011b; Joos et al., 2012; Van der Loo et al., 2009; Vanneste et al., 2014a) and may be the most pertinent factor for predicting psychological and somatic disturbance in TI (Vanneste et al., 2010).

One previous study that explicitly addressed this question observed the recruitment of distinct neural circuits tied to depression and distress in the tinnitus brain (Joos et al., 2012). In this study, a source estimation using sLORETA revealed a correlation between distress and modulations in the α- and β-bands over the right frontopolar and orbitofrontal regions, and changes in the