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Selective attentional impairment in chronic tinnitus: Evidence from an event-related potentials study

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HIGHLIGHTS

- Attentional dysfunction as frequently reported in chronic tinnitus was tested with a P300 novelty task.
- P3a amplitude was significantly lower in tinnitus subjects than in controls.
- Tinnitus is related to a specific impairment in attentional switching to salient events.

ABSTRACT

Objective: Tinnitus is an auditory phantom sensation experienced in the absence of a sound source. Cognitive dysfunctions, especially in working memory and attention, are frequently reported to be associated with tinnitus. The aim of this study was to investigate attentional functioning in a group of subjects with chronic tinnitus using ERPs, and in particular the P300 components.
Methods: We studied 20 patients with chronic tinnitus and 20 healthy subjects that performed a P300 Novelty task.
Results: P3a amplitude was significantly lower in tinnitus subjects than in controls. P3a latency was comparable in patients and controls. The P3b parameters were similar in the two groups. N1 latency for all the stimuli was significantly longer in tinnitus subjects than in controls.
Conclusion: These results point to a general slowing in early stimulus perception in tinnitus subjects. Moreover, a specific difficulty emerged in attentional switching to unexpected events during an orienting response, probably owing to a dysfunction in the ventral attention network.
Significance: Psychophysiological approach reveals selective attentional impairment and could provide useful data for rehabilitative strategies in chronic tinnitus.

1. Introduction

Tinnitus is an auditory phantom sensation experienced in the absence of a sound source (Eggermont and Roberts, 2004, 2012). Tinnitus is a common symptom that is perceived as chronic by 10–15% of adults (Heller, 2003; Henry et al., 2005), 10–20% of whom report that it interferes with their everyday life (Leske, 1981; Quaranta et al., 1996). It is usually described as a ringing noise, though some patients experience a high-pitched whining, hissing or steady tone.

The prevailing opinion is that tinnitus is a consequence of a series of plastic changes that affect the whole auditory chain and are caused by damage to the peripheral auditory structures (Eggermont and Roberts, 2004). While the loss of afferent input to the primary auditory system can initiate tinnitus, central mechanisms play an important role in maintaining the disorder. Increased neural firing and tonotopic map reorganization in auditory cortical structures has been observed (Kaltenbach, 2000; Norena and Eggermont, 2003; De Ridder et al., 2007). Increased

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spontaneous activity has also been described in many brain non-auditory areas, including the anterior insula (AI) (Mirz et al., 2000a; Sadaghiani et al., 2009), frontal and cingulate cortices (Mirz et al., 1999; Weisz et al., 2005) and subcortical structures such as the cerebellum (Shulman and Strashun, 1999). The cerebellum in particular has been hypothesized to be a possible generator of auditory phantom symptoms (Bauer et al., 2013). The tinnitus percept has also been associated with connectivity changes between limbic/parahippocampal areas (De Ridder et al., 2006; Leaver et al., 2011), prefrontal/parietal associative cortices and subcortical structures, with possible changes in the functioning of attentional and emotional brain networks (Maudoux et al., 2012; Burton et al., 2012) that may explain the cognitive and psychiatric dysfunctions observed in such subjects.

Psychiatric distress such as anxiety and depression constitute important comorbid factors that affect the quality of life of subjects with tinnitus (Folmer et al., 2001). Tinnitus sufferers also report impaired cognitive functions (Hallam et al., 1988; Erlandsson and Hallberg, 2000), particularly in working memory and attention. Indeed, previous studies have described deficits in the executive control of attention (Heeren et al., 2014) as well as in attentional shifting (Hallam et al., 2004) and selective and divided attention (Rossiter et al., 2006; Stevens et al., 2007). It has also been suggested that attentional deficits in tinnitus subjects may be related to a general impairment in cognitive processing speed (Das et al., 2012).

The tools that have previously been used to investigate attentional functioning include event-related potentials (ERPs) (Duncan et al., 2009). ERPs reflect cognitive operations that are linked to a physical or mental event and are recorded from the human scalp by means of electroencephalogram (EEG) signals (Duncan et al., 2009). The amplitude of the ERP components is closely related to the amount of attentive resources that are relevant to the task, while their latency is associated with the stimulus evaluation time (Verleger, 1997; Luck, 2005).

The P300 is the most studied ERP component for exploring selective attentional functions. It can be elicited during a P300 novelty task during which two different components emerge, the P3a and the P3b (Friedman et al., 2001; Polich and Criado, 2006; Polich, 2007). The P3b is evoked when the subject has to discriminate the significant stimulus (target) among non-significant (standard) stimuli and it is therefore related to the attentional selective discrimination and the subsequent storing of meaningful stimuli (Polich, 2007; Kim, 2014). The P3a is evoked when rare interspersed distracter stimuli (novel) are included in the same task (Friedman et al., 2001), reflecting the attentional switching to salient stimuli during an orienting response (Polich, 2007; Kim, 2014). These components are thought to reflect the functioning of selective brain areas activated during an attentional task. In particular, the P3a is believed to activate the frontal brain areas, whereas the P3b is more closely related to the temporal-parietal activity.

The aim of this study was to examine attentional functioning in a group of subjects with chronic tinnitus using the P300 components. On the basis of the psychophysiological meaning of these components and the previous reports of attentional impairments in tinnitus, we expected to find reduced amplitudes and prolonged latencies of the two P3 components in tinnitus subjects.

2. Methods

2.1. Design

We used a cross-sectional design to compare a group of tinnitus sufferers with an age- and sex-matched control group.

2.2. Subjects

Twenty consecutive tinnitus subjects (TS) (8 males; average age: 50.1 ± 11.1) and 20 sex- and age-matched controls (8 males; average age: 49.4 ± 10.9) were recruited for the study from April 2015 to June 2016 at two metropolitan hospitals in Rome (Tinnitus Center of European Hospital and Hearing Center of Policlinico Umberto I).

Patients underwent a standard audiological evaluation performed by an ENT doctor. Only patients with chronic tinnitus, defined as tinnitus audible every day for over six months, and with normal hearing (NH) (hearing threshold up to 20 dB HL) at least up to 2000 Hz were included in the study. Audiograms yielding values over 2000 Hz could be either normal or correspond to presbycusis (high frequency hearing loss – HFHL). In the latter case, hearing loss could not exceed 30 dB HL at the worst frequency (mild HFHL). All subjects had normal transient evoked otoacoustic emissions. Moreover, tinnitus sufferers were selected if brainstem auditory-evoked potential (BAEP) showed normal pattern and no focal lesions were found in brain magnetic resonance imaging and no epileptic abnormalities emerged in resting EEG upon visual inspection. Exclusion criteria were: pulsatile tinnitus, Ménière's disease, otosclerosis, history of neurological and psychiatric disorders as assessed by means of the DSM-IV-R, substance abuse or ongoing therapies based on drugs that act on the central nervous system, particularly benzodiazepines, selective serotonin reuptake inhibitors and antiepileptic drugs. Upon enrolment, the tinnitus handicap inventory (THI) was used to grade tinnitus severity in all the patients. The THI is a self-report questionnaire based on 25 items that explore the extent of tinnitus-related distress (Passi et al., 2008). The main clinical characteristics of the tinnitus patients are shown in Table 1.

All of the subjects in the control group were volunteers who were consecutively recruited from among the relatives of the tinnitus outpatients and the staff working at our hospitals in the same period of time. The control subjects were all screened for audiological, neurological and psychiatric disorders. All controls have normal hearing and none of them were taking any medications.

All the subjects enrolled in the study underwent the Mini-Mental State Examination to rule out the presence of dementia. Written informed consent was obtained from all the participants prior to the evaluation, and the study was approved by the Local Medical Ethics Committee.

Table 1
Demographic and clinical variables for patients and controls.

	TS (20)	Controls (20)	P^{*}
Age (yrs)	50.1 ± 11.1 (49)	49.4 ± 10.9 (51)	0.91
Sex (M/F)	8/12	8/12	1**
Education (yrs)	15.2 ± 2.2 (15.5)	15.5 ± 2.2 (16)	0.72
MMSE	29.8 ± 0.5 (30)	29.9 ± 0.2 (30)	0.58
BDI	7.1 ± 4.2 (6)	5.4 ± 2.7 (6)	0.29
STAI Y1	36.6 ± 7.9 (35)	34.0 ± 3.4 (33.5)	0.37
STAI Y2	38.3 ± 5.6 (40)	35.1 ± 4.7 (34.5)	0.07
Tinnitus characteristics			
Duration (months)	22.3 ± 14.2 (21)	–	–
Presence on a day (hours/die)	14.1 ± 7.3 (12)	–	–
Location (monolateral/bilateral)	11/9	–	–
NH/mild HFHL	12/8	–	–
THI – basal	30.3 ± 15.1 (32)	–	
THI – pre ERPs	29.5 ± 14.5 (31)	–	

M: male; F: female; MMSE: Mini Mental State Examination; STAI Y-1: State-Trait Anxiety Inventory State score; STAI Y-2: State-Trait Anxiety Inventory Trait score; BDI: Beck Depression Inventory.
THI: Tinnitus Handicap Inventory.
Data are expressed as mean ± standard deviation (median).
* Mann–Whitney *U* test.
** χ^2 for categorical data. Significance level is set to $p \leqslant 0.05$.