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Research report

Increased cortical surface area of the left planum temporale in musicians facilitates the categorization of phonetic and temporal speech sounds

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ABSTRACT

We measured musicians and non-musicians by using structural magnetic resonance imaging to investigate relationships between cortical features of the left planum temporale (PT) and the categorization of consonant-vowel (CV) syllables and their reduced-spectrum analogues. The present work is based on previous functional studies consistently showing that the left PT is particularly responsive to transient acoustic features in CV syllables and their reduced-spectrum analogues, and on striking evidence pointing to structural alterations of the left PT as a function of musicianship. By combining these two observations, we hypothesized to find that differences in cortical surface area (SA) and cortical thickness (CT) of the left PT in musicians may facilitate the categorization of fast-changing phonetic cues. Behavioural results indicated that musicians and non-musicians achieved a comparable performance in the categorization of CV syllables, whereas the musicians performed significantly better than the controls in the more demanding reduced-spectrum condition. This better behavioural performance corresponds to an increased cortical SA of the left PT in musicians compared to non-musicians. No differences in CT of the left PT were found between groups. In line with our predictions, we revealed a positive correlation between cortical SA of the left PT in musicians and the behavioural performance during the acoustically more demanding reduced-spectrum condition. Hence, we provide first evidence for a relationship between musical expertise, cortical SA of the left PT, and the processing of fast-changing phonetic cues.

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1. Introduction

In the last two decades, a diversity of anatomical measurement techniques has been used to uncover the morphological characteristics associated with exceptional behavioural skills in a variety of domains (Bermudez et al., 2009; Draganski et al., 2006; Elmer et al., 2011a, 2011b; Hänggi et al., 2010; Munte et al., 2002). In particular, previous work provided evidence for structural differences in brain regions of professional musicians supporting motor (Bangert et al., 2006; Bermudez et al., 2009; Gaser and Schlaug, 2003a, 2003b; Imfeld et al., 2009), cognitive (Bermudez et al., 2009; Sluming et al., 2002, 2007), and auditory-related functions (Bermudez et al., 2009; Gaser and Schlaug, 2003a, 2003b; Schlaug et al., 1995). Concerning the latter, one of the most frequently replicated findings was the observation of an altered grey matter architecture of the left planum temporale (PT) as a function of musical training (Bermudez et al., 2009; Keenan et al., 2001; Luders et al., 2004; Schlaug et al., 1995).

The left PT has originally been considered to be a speech-selective area (Galaburda et al., 1978). However, meanwhile there is a general consensus that the left PT is not only involved in processing speech-specific information. In fact, in a previous work Griffiths and Warren (2002) proposed that the PT acts as a computational engine which is engaged in segregating and matching spectro-temporal acoustic features. In addition, based on a spectro-temporal framework proposed by Poeppel (2003), it is assumed that this computational engine works in a slightly asymmetric manner. According to this framework, the left PT is particularly sensitive to rapidly changing acoustic cues, whereas its right counterpart is more likely involved in processing slow acoustic modulations, regardless of the nature of the acoustic signal (i.e., speech or music). Objective evidence for a relative superiority of the left auditory-related cortex in processing fast-changing acoustic cues arises from previous functional work showing that the left PT is particularly responsive to consonant-vowel (CV) syllables and reduced-spectrum analogues (Jancke et al., 2002; Zaehle et al., 2004). In this context, it has repeatedly been shown that the discrimination of stimuli varying in voice-onset-time (VOT), which is the time range between the release of a stop consonant and the onset of vocal folds vibrations, primarily relies on the functional capacity of the left PT (Jancke et al., 2002; Meyer, 2008; Zaehle et al., 2004).

Based on previous evidence showing that the left PT is (1) fundamentally involved in the processing of CV syllables and their reduced-spectrum analogues (Jancke et al., 2002; Zaehle et al., 2004), and (2) that the anatomy of this auditory-related brain region may differ as a function of musical training (Bermudez et al., 2009; Keenan et al., 2001; Luders et al., 2004; Schlaug et al., 1995), in the present work we measured musicians and non-musicians and assessed putative relationships between cortical surface area (SA) and cortical thickness (CT) of the left PT and the categorization of fast-changing speech and non-speech sounds. With this purpose in mind, we postulated a strong a-priori hypothesis and performed SA and CT analyses only for two regions of interest, namely the left and right PT. We hypothesized to find a relationship between grey matter architecture of the left (but not in the right) PT in musicians and their performance during the categorization of CV syllables (i.e., speech condition) and reduced-spectrum analogues (i.e., non-speech condition). For reasons of completeness, we also report the results of exploratory whole-brain CT and SA analyses. However, since we did not have specific a-priori hypotheses concerning the relationships between anatomical regions residing outside the PT and behaviour, we abstained from extensively discussing these exploratory **results and report them** as Supplemental material.

2. Materials and methods

2.1. *Subjects*

Thirteen professional musicians [seven females and six males; mean age = 25.15 years, standard deviation (SD) = 5.74 years] and 13 control subjects without formal musical education (six females and seven males; mean age = 25.30 years, SD = 3.52 years) participated in this study. All musicians commenced their musical training before the age of 7 years (mean age of practice commencement = 6.22 years, SD = 1.06 years), and none of them was a vocalist. The musician group consisted of three flautists, one harpist, three pianists, three violinists, two cellists, and of one guitarist. Non-musicians never had any musical practice with the exception of obligatory flute lessons at school. All subjects had a similar level of education (university degree or students) and were comparable in the number of foreign languages spoken. The subjects reported no past or current neurological, psychiatric, or neuropsychological problems, and denied the consumption of drugs or illegal medication. Subjects were paid for participation, the local ethics committee approved the study, and written informed consent was obtained from all participants. All subjects were consistent right-handers as revealed by the Annett Handedness Inventory (Annett, 1970).

2.2. *Behavioural data*

2.2.1. *Music aptitudes*

All subjects performed an auditory test specifically designed to test musical aptitudes (Gordon, 1989). This test consisted of 30 successive trials in which the subjects had to compare pairs of piano melodies, and to decide whether these were equivalent, rhythmically different, or tonally different. Due to technical problems, one subject of the control group could not be tested.

2.2.2. *Cognitive capability*

The KAI (Kurztest für allgemeine Basisgrössen der Informationsverarbeitung) test (Lehrl and Fischer, 1992) was applied in order to rule out global differences in intelligence between the two groups. This procedure permits to estimate the actual cognitive capability (fluid intelligence) of the subjects.

2.3. *Stimulus material*

The same stimulus material we used in the present study has already been reported in a previous work of our group (Elmer

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