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The neural substrates of chanted vowel changes in rhythm sequences

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Introduction

Singing has been reported to be a supporting approach e.g. in the treatment of patients suffering from motor speech disorders or aphasia. So far singing studies have investigated monotonic or melodically intoned singing or singing a harmonization with a melody (Perry et al. 1999; Brown et al., 2004; Özdemir et al., 2006; Gunji et al., 2007). Within this context rhythmical aspects of singing have been neglected. Our objective was to investigate chanting of vowel changes in 3 different rhythm tasks with increasing complexity in contrast to chanting single vowel repetitions as control condition. These tasks are already approved in therapy and are the basis of further research with patient groups. The cortical network activated by singing is often reported to show right hemisphere asymmetries in motor and auditory regions, therefore we are particularly interested in examining the potential influence of rhythm structures on lateralization.

Methods

Participants:
15 male and 13 female healthy right-handed non-musicians
mean age 26.3 (range 21-41).

Stimuli:
Stimuli consisted of metrical quadruple measure groupings with a duration of 4sec. which were chanted as sequences of (a) isochronous vowel changes, (b) vowel changes with even groupings, and (c) vowel changes with uneven groupings. Single isochronous vowel repetitions served as control condition. The auditory stimuli were presented by fMRT compatible headphones (Resonance Technology).
The stimuli consisted of vowel change repetitions in order to avoid lexical or semantic components of speech processing and to focus on phonological processing as the basis of further research with groups of patients mentioned above. In order to reduce the influence of melodic components we choose a monotonous pitch repetition (chanting).

Task:
The experiment was conducted in an event-related design. The stimuli (4 different groupings for each condition / 1 control condition) were presented in a pseudo randomized order and jittered around an interstimulus interval of 6 sec. Subjects had to listen and to immediately repeat the heard stimuli after the presentation had stopped. The paradigm was implemented in Presentation (Neurobehavioral Systems) and synchronized to the scanner.

Data acquisition:
185 volumes each consisting of 41 contiguous transversal slices, with a thickness of 3.4 mm, were acquired using a T2*-weighted EPI sequence on a 3T Siemens Trio MRI-system.
TR 2200ms, TE 30ms, FOV 240, FA 90°, Voxel size: 3.44 x 3.44 x 3.74

Data analysis:
Imaging data were analyzed using SPM8b. The reported results were derived from a random-effects group analysis with an FWE-corrected p-value of p=0.05 and an extent threshold of 10 voxel.

References

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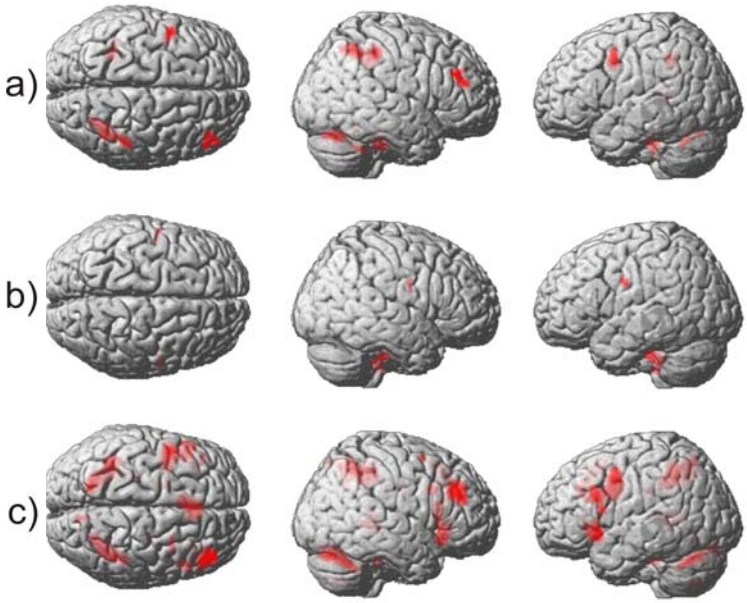
Results



All three conditions yielded significant activations of the premotor cortex (BA6) in the left hemisphere, and in the brainstem in contrast to the control condition.

Condition (a) yielded additional significant bilateral activations of the cerebellum and the inferior parietal lobe (BA40) most prominent in the right hemisphere. The middle frontal gyrus (BA46) was exclusively activated in the right hemisphere.

Condition (b) resulted in an additional significant activation of the premotor cortex (BA6) in the right hemisphere.

Condition (c) shows additional significant bilateral activations of the cerebellum, the inferior frontal gyrus (BA47) and insular cortex (BA13) most prominent in the left hemisphere as well as in cingulate gyrus (BA32). A significant activation of Broca's area (BA44,45) was exclusively found in the right hemisphere. The inferior parietal lobe (BA40) was also significantly activated bilateral.

Discussion

Parietal, cerebellar, and frontal activations during rhythm discrimination and production have been reported before from different research perspectives (music, language, neuropsychology) although not in connection with singing. The often described right hemisphere asymmetry in motor regions during singing can only partially be confirmed by our study. According to our results rhythm structure seems to be a decisive factor not only regarding lateralization but also regarding activation of specific brain areas during singing. The higher the working memory and motor demands the more left inferior frontal activations occurred, an area which is described in connection with temporal processing and sequencing behaviors. We assume that the reason for the lower amount of activations in condition (b) -although rhythmically more demanding than condition (a)- was the metrically even legato chanting with comparatively long pitch durations and even articulatory movements which had greater similarity with the control condition.
In following studies with patients suffering from aphasia and apraxia of speech we will investigate how relevant our results will be in the context of therapy interventions.

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