fMRI of Voice Production

J. Baudewig[1], A. Olthoff[2], E. Kruse[2], P. Dechent[1]

[1]MR-Research in Neurology and Psychiatry, University of Göttingen, Göttingen, Germany, [2]Dept of Phoniatrics and Pedaudiology, Medical Faculty, Georg-August-, Göttingen, Germany

Introduction

In contrast to language processing with classical left lateralised broca and wernicke areas little is known about corresponding regions related to voice production. A crucial part in voice production is the motor function of the larynx. Activations in voice box related sensorimotor areas as describe already by Penfield [1] were found e.g. by swallowing. During recognition and differentiation of auditory stimuli activation were also found in the superior temporal sulcus [4]. In a previous study [5] using TMS we found a different localisation of the sensorimotor cortex related to the voice box. Here we focused on activations during voice production. Goal of our study was to establish a detailed activation map of sensorimotor areas related to the larynx.

Methods

BOLD fMRI was performed at 3 Tesla (Siemens Trio) using EPI (TR 2000ms, TE 36ms, 22 slices, 2x2x4mm³) on 16 healthy volunteers (2 male, mean age 29). In a typical block design (12 s stimulation alternating with 18 s control, 10 repetitions) 5 different experiments were performed:

(1) Sequential finger opposition [mapping of the sensorimotor hand area]
(2) Closing of the vocal fold [mapping of sensorimotor areas of the larynx without any phonation]
(3) Phonation without intonation
(4) Auditory stimulation using the volunteers own voice singing quints (recorded prior to the fMRI session)
(5) Active phonation with intonation [singing the same quints as in (4)]

The order of these experiments was randomised despite the fact that (5) was immediately following (4) in order to achieve comparable intonation and dynamic of the voice production during both tasks. Evaluation was done with BrainVoyager-QX® including motion correction, Talairach-Normalisation, and subsequent application of a GLM.

Results

The finger opposition task resulted in well known activations in the motor network, including sensorimotor cortex, serving as landmarks for the activations during voice production. Tasks involving motor activity in the voice box (2, 3 and 5) induced several activations along the central sulcus (Fig. 1). The most apical localisation in the sensorimotor cortex was found in a bilateral pattern medial to the well known hand area (Fig1. / right). Caudal to the hand area again a bilateral region along the central sulcus was activated during phonation as well (Fig.1 / middle). Even more caudal activations close to the sylvian fissure were found during tasks involving motor control of the voice box as well as during auditory stimulation (Fig.1 / left). Additionally, we found activations in basal ganglia as well as in premotor cortex and cerebellum. Bilateral activation at the auditory cortex where found during voice production as well as during pure auditory stimulation. In contrast to language tasks and another study using a singing [4] we found no hints for any lateralisation.

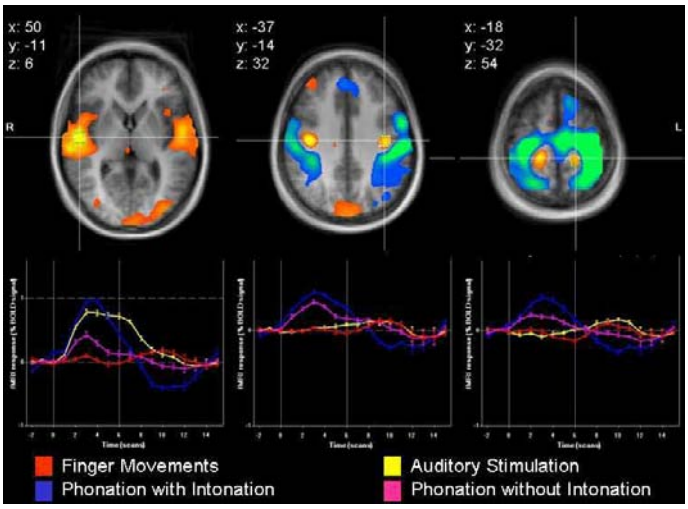

***Figure 1**: BOLD activations induced by motor activity in the voice box (red-yellow) and finger movements (blue-green). At the caudal end of the central sulcus motor activity could not be certainly assigned to voice box activity due to the neighing auditory cortex (left). Bilateral motor activity during both phonation tasks was found caudal of the hand area (middle) as well as in a more medial and apical area (right).*

Discussion

The most apical activations (Fig1. / right) during the task involving motor control of the laryngeal muscles (experiments 2, 3 and 5) were also found in other studies [e.g. (3)]. Due to known organization of the human homunculus and the fact, that all these experiments include controlled expiration, we ascribe these activations to motor control of breathing. The activations at the caudal end of the central sulcus (where laryngeal representation were suspected) could not be doubtlessly explained by motor control of the voice box because these regions were also found activated during pure auditory stimulation. Our main finding is the laryngeal representation in the sensorimotor cortex below the hand area but clearly above the lower end of the central sulcus (Fig.1 / middle). Further support for this localization of the laryngeal cortex arises from our former TMS experiment (5) where the optimal scalp position for the TMS coil to evoking a EMG response in laryngeal muscles (vocal fold, cricothyroid muscle) was found 8 cm lateral from midline (Fig.2).

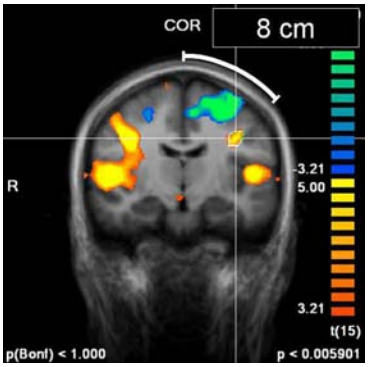

***Figure 2**: Comparison of BOLD activations by motor activity in the voice box to results from a mapping experiment where TMS was used to localize the cortex innervating the laryngeal muscles.*

References

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