Stimulus-evoked response in cutaneous veins as measured by whole brain fMRI

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INTRODUCTION

Cognitive and emotional processes induce changes in peripheral physiology. At the same time afferent information from the body influences the subjective experience of emotional states, learning and decision making processes[1]. Taking account of this complex relationship an increasing number of fMRI studies are complemented by measurements of task-evoked changes of the heart rate, the pupil size or the skin conductance[2]. These parameters reflect changes in the autonomic nervous system and may be employed as indicators of emotional and cognitive processes and regressors for fMRI analysis.

However, such studies require additional pieces of equipment and experimental effort. Here we show that by exploiting the physiological data, which is already contained in the fMRI scan, these drawbacks may be circumvented. The human scalp as a strongly innervated organ gives rise to fMRI signals, which are usually neglected in fMRI analyses. We demonstrate that by analyzing signal changes induced by stimulus evoked venous constriction in the scalp, information about bodily arousal can be extracted.

METHODS AND MATERIALS

Five subjects (four male, mean age ± SD = 31.4±5 y) were scanned in a 3 T Siemens scanner equipped with a 32 channel coil. The subject performed the N-back task[3] (30 s 2-back task 30 s of 0-back) which is not imposing particular emotional stress. Two EPI scans covered the whole brain (resolution 3×3×3 mm^3, 37 nearly axial slices, T_E/T_R= 30 ms / 2000 ms, GRAPPA factor 2) and two additional higher-resolution runs covered only the forehead (resolution 1.5×1.5×2 mm^3, 15 slices, T_E/T_R=30ms/2000ms). 3D phase-contrast MR angiography of the head vessels and a T_1w anatomical scan were acquired for every subject. Skin conductance was measured on the left hand's middle and ring finger with the help of GSX Brain amplifier (Brain Products GmbH, München).

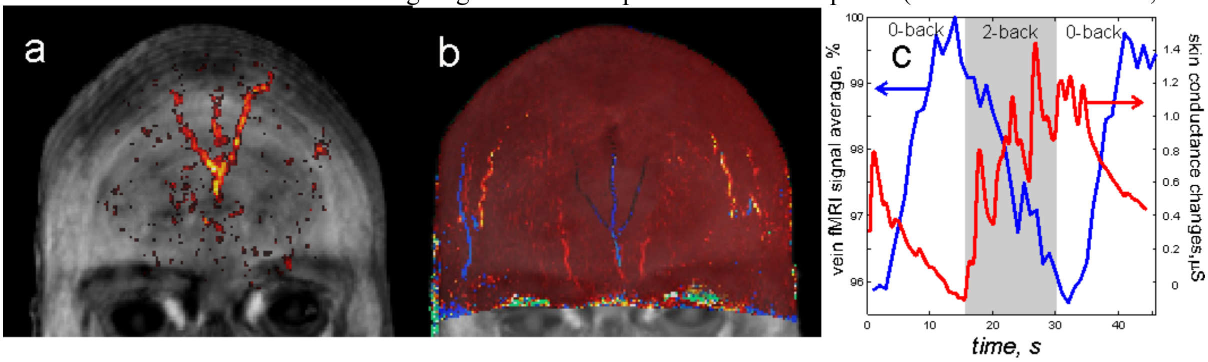

Fig. 1(a) High resolution fMRI activation map of single subject overlaid on the 3D surface reconstruction of a T_1w anatomical image; (b) Phase-contrast angiography of the same subject: veins and arteries are depicted in blue and read, respectively; (c) fMRI signal average over all voxels of scalp veins and EDA response to the task.

RESULTS

The increased skin conductance during N-back task (N=2) as compared to N=0 was found in 4 of 5 subjects (see Fig. 1c).

Due to the longer T_2^* of blood as compared to skin big vessels are well recognizable on both high and low resolution EPI images. We found strong stimuli-locked variation of the MR signal in the big vessels (see Fig. 1c). The signal monotonously decreases during the 2-back block and returns to baseline during the control task (0-back). To model this process in GLM analysis we used a sine function with a period equal to the double block length and phase locked to task onset (see Fig. 1c). The resulting activation map for a high resolution scan of single subject is shown on the Fig. 1a. As can be seen on the corresponding PC-angiography (see Fig. 1b) voxels in the forehead which show the task-evoked signals variation are co-localized with veins draining the scalp (supraorbital and supratrochlear veins). Similar results were obtained for 4 of 5 subjects. One subject did not show any task-evoked changes in the venous signal. The lower resolution scans (not shown) gave similar signal changes and activation patterns.

DISCUSSION

Cutaneous veins are sympathetically innervated and venous constriction has been reported in response to mental arithmetic, stress, emotional stimuli and temperature fluctuations[4]. The observed task-evoked changes in the fMRI of veins can be attributed to the changes in blood volume, blood flow velocity and blood oxygenation level. We hypothesize that main contribution is blood volume changes due to sympathetically induced vein constriction. Thus information about sympathetic outflow can be extracted from conventional fMRI measurements with no additional experimental effort helping to improve the fMRI analysis, even of existing data.

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