Detection of blood flow changes during cognitive task activation using CASL

T. Mildner[1], S. Zysset[1], R. Trampel[1], W. Driesel[1], H. E. Möller[1]
[1]Max Planck Institute of Cognitive Neuroscience, Leipzig, Germany

Abstract
Multi-slice perfusion-based fMRI (p-fMRI) is demonstrated with a color-word matching Stroop task as an established cognitive paradigm. Continuous arterial spin labeling (CASL) was achieved using a circular coil of 6-cm diameter placed over the left common carotid artery. CASL was applied for all repetitions of the functional run in a quasi-continuous fashion, i. e. it was interrupted during image acquisition only. For comparison, BOLD contrast was detected using GE-EPI. Positive activations in BOLD imaging were found in p-fMRI as negative signal changes. Negative BOLD signals ("deactivation") appeared as positive signals in p-fMRI indicating areas with decreased cerebral blood flow (CBF).

Introduction
Perfusion-based fMRI has been shown to be a tool for investigating task-related brain activity (1). The approach is expected to have a potentially better localization of activation and permits the quantification of changes in CBF. Compared to conventional BOLD imaging, a lower sensitivity, a reduced number of slices, and an increased sampling interval limited its use to the detection of blood flow changes in primary cortices such as the motor or the visual cortex. In the present study, p-fMRI was applied to a color-word matching Stroop task as an example for a cognitive paradigm. The Stroop experiment is known to produce robust activation in a number of brain regions (2).
CASL was achieved by the use of separate labeling and imaging coils (3). With this method, magnetization transfer effects can be eliminated, and multi-slice perfusion imaging can easily be implemented. Recently, the method was applied in a p-fMRI study to map CBF changes quantitatively in subjects performing a motor paradigm (4). In this work, optimization of the perfusion imaging procedure to detect cognitive task activation allowed the acquisition of 8 slices with a sampling interval of 3 seconds.

Method
All experiments were performed using a 3-T whole-body scanner (*Bruker Medical, Ettlingen, Germany*) with a helmet resonator for image acquisition. For functional perfusion imaging, a spin-echo EPI sequence with a 64 x 36 acquisition matrix was used (acquisition bandwidth 100 kHz, TE = 13 ms, echo position = 11.1 %). The reconstruction to 64 x 64 was performed by a half-Fourier technique. Eight axial slices were recorded with a FOV of 19.2 cm and a voxel size of 3 mm x 3 mm x 5 mm. BOLD imaging was performed in the same session using a standard GE-EPI protocol with TE = 30 ms, TR = 2 s and identical slice positions as employed for p-fMRI.
For CASL, a circular coil of 6-cm diameter was used under pulse-program control. This coil was placed over the left common carotid artery of the subject. A continuous RF pulse with a power of approximately 1.0 W was applied during the labeling period. The gradient strength, needed to fulfil the adiabatic condition, was adjusted to 0.2 Gcm^{-1}. Labeling was applied for a period of 2.5 s within each repetition (TR = 3 s) during the entire experiment. Slices were acquired during the last 500 ms of the TR interval.
For task activation, a color-word matching Stroop task (2) was used. Briefly, two conditions are involved in the task. In each condition the subject has to determine whether the color of the symbols presented in the top row matches the color-word on the bottom row (printed in black). In the neutral condition, the top row just contained a row of four 'X's whereas in the incongruent condition the top row had a color-word printed in a incongruent color. The tasks were presented using a blocked design with 12 s of rest followed by either 24 s with the neutral or the incongruent condition. At present, a total of 5 volunteers was investigated.

Fig. 1. Sagittal and axial cuts showing the activations obtained in the Stroop experiment using p-fMRI (left) and BOLD-fMRI (right) with thresholds of z = 2.33 and z = 3.09, respectively. Positive or negative signal changes are given in the yellow-red or blue-white color scale, respectively.

Results
The activation maps for p-fMRI and BOLD-fMRI each averaged over 5 subjects who performed the color-word matching Stroop task are shown in Figure 1. Positive and negative BOLD signal changes were detected mainly in the left (i. e. the labeled) hemisphere of the brain as expected (2). In most of these brain areas, p-fMRI shows signal changes of opposite sign. However, these areas are rather small compared to the wide-ranging positive or negative BOLD activations. The difference between the size of activations between BOLD and p-fMRI was strongest in the region of the intraparietal sulcus and the precuneus. The correspondence between negative BOLD and positive perfusion signal changes suggests, that in these brain areas a decrease in CBF occurs which is associated with a deactivation during the Stroop task.

Conclusion
Functional perfusion imaging by use of CASL at the human common carotid artery was applied to a cognitive paradigm, that produces activations in a number of brain regions. BOLD-fMRI showed regions with positive and negative signal changes which were detectable by means of p-fMRI and exhibit the opposite sign. Such measurements could be a valuable tool to identify a deactivation of the brain related to a decrease in CBF. The observed sensitivity profile of p-fMRI throughout the brain and the localization and size of activations compared to BOLD-fMRI need further investigation.

References
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