Randomized fMRI-designs with event-related FLASH: A Technique for Monitoring Cerebral Pain Processing

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Introduction

Cerebral pain processing is reported to involve several areas of the brain, and the conditions under which specific regions are active in pain perception are not yet fully understood. For that reason and because the regions of activation seem to be very small [1], the correct assignment of functional activation to anatomical structures is crucial. Recent studies [2,3] have used functional MRI based on EPI techniques for investigation of experimental pain. Although EPI offers a high temporal resolution, these techniques suffer from in-plane distortion artifacts and a lower Signal-To-Noise-Ratio (SNR), compared to other imaging methods. On the other hand, habituation to painful stimuli is reported [3], which limits the total number of stimuli per experimental session. We present first results acquired with an event-related FLASH technique (reducing in-plane distortion) and a randomized stimulation design (reducing habituation) with three different thermal pain intensities and a somatosensory control stimulus.

Materials and Methods

Two healthy volunteers were examined in a circular polarized head coil of a standard 1.5 T clinical whole body scanner (Magnetom VISION, Siemens, Germany) during contact heat pain stimulation at three individually calibrated intensities (warm, pain-threshold, painful), which were applied in (pseudo-) randomized order (see Fig.1). An MR compatible thermode system (TSA2001, MEDOC, Israel) was used for stimulation at the left foot of the subjects, just below the ankle. The base temperature of the thermode was 34°C, warm stimulation 38°C, pain threshold was at 43°C and 46°C, respectively, painful stimulation was 2°C above the volunteer's predetermined pain threshold. Overall stimulus duration was 3 seconds. After applying three thermal stimuli, the thermode temperature was set to baseline and a vibrotactile pulse was applied via a pneumatic clip mounted 2 cm distally of the thermode. This signal informed the voluteer to report the thermal stimulation order by pressing three buttons of a computer mouse.

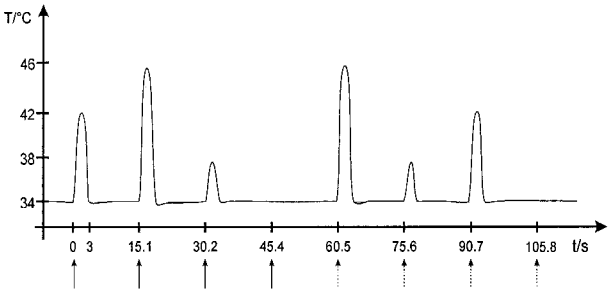

Fig. 1: Stimulus application; measured temperature vs. time. The arrows denote the acquisition of the first (solid) and the second (dashed) line of k-space of the first image of the time series with respect to the appropriate pain intensity.

A modified T2*-weighted FLASH sequence [4] (TE/TR/α/FOV/MAT/TH=56ms/84ms/40°/240mm*180mm/128²/4mm) was used to measure a time series of 45 images in 2 transversal and 2 sagittal slices. In order to achieve a temporal resolution of 336 ms, a single line of k-space is acquired after the application of one stimulus. This is repeated 56 times to fill half of the matrix. The image is then reconstructed by using a home-made projection onto convex sets (POCS) algorithm. The application of the stimulus was synchronized with the continuously running MR-sequence. Functional images were constructed based on correlation analysis using a half sine function as template. Functional maps (correlation coefficient cc > 0.6) were superimposed on T1-weighted spin-echo images.

Results and Discussion

The functional maps (see Fig. 2) show an activation of the anterior cingulate cortex only after warm stimulation, activity of posterior cingulate cortex and the insula region (not shown) after both warm and painful stimulation (⇦). The activity of SI increases from baseline, warm to heat stimulation, while it is absent in painful stimulation (⎍). Frontal lobe activity was observed both in baseline and painful stimulation (↘). The activation in the frontal lobe during the baseline stimulus may be due to activating working memory areas because the subject tries to recall the order of thermal stimulation. The results are in line with other studies [3,5], reproducing the observation of [5] for SI .

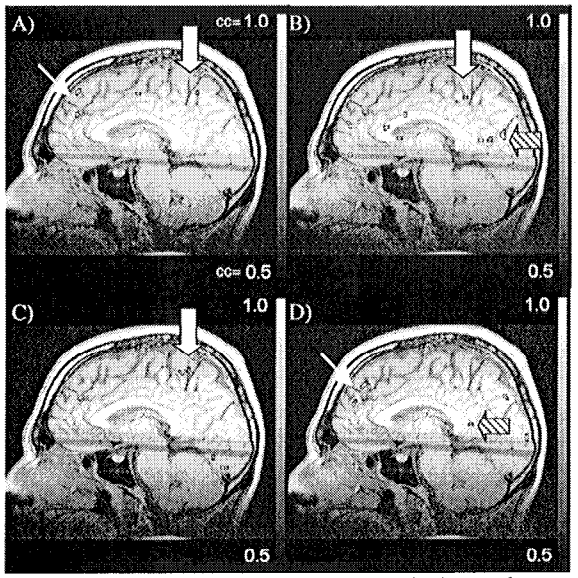

Fig. 2: Functional map overlayed on a T1-weighted sagittal spin-echo image of the right hemisphere. A) baseline, B) warm, C) pain-threshold, D) painful stimulation. The signal losses are due to spin history effects of the previously acquired transversal slices.

Conclusion

The event-related FLASH technique provides the possibility to acquire several slices with an equal temporal resolution as EPI sequences. Since the stimulus application is performed in randomized order, habituation effects at high stimulus frequencies can be reduced. The somatosensory control stimulation provides a "localizer" for primary somatosensory areas and might help to evaluate the role of SI in pain processing, which is still discussed controversally [3,5]. This technique may help to evaluate cerebral pain processing in more detail.

References

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