Assessment of prospective motion correction using optical tracking system for reduction of stimulus-correlated false positive activations in high spatial resolution functional magnetic resonance imaging

Ikuhiro Kida[1,2], Takashi Ueguchi[1,2], Yuichiro Matsuoka[1,2], and Maxim Zaitsev[3]

[1]*Center for Information and Neural Networks, National Institute of Information and Communications Technology, Suita, Osaka, Japan,* [2]*Graduate School of Frontier Biosciences, Osaka University, Suita, Osaka, Japan,* [3]*University Medical Centre Freiburg, Freiburg, Germany*

TARGET AUDIENCE: Researchers using fMRI

PURPOSE

Functional magnetic resonance imaging (fMRI) at ultra-high magnetic field (UHF) has a great sensitivity, which leads to an increase the achievable spatial and temporal resolution. Although fMRI with high spatial resolution can potentially detect locations of brain activations with a higher precision, head motion may impact results of fMRI because the task-related head motion can produce false-positive activations (FPA)[1]. Prospective motion correction (PMC) using external position information based on optical tracking has been employed for MR improving scanning process[2]. Recently, PMC using external position information has been evaluated for fMRI studies but not at UHF[3] or not at high spatial resolution[4]. In the present study we evaluated the PMC using optical tracking system for fMRI research with 1 mm isotropic resolution at 7T. We designed a pseudo fMRI paradigm for a motion phantom to simulate a motion-related FPA. Motor tasks in human subjects were employed for PMC evaluation in vivo.

MATERIALS AND METHODS

All experiments were performed on a 7T whole-body MRI scanner (Siemens Healthcare, Erlangen, Germany) with an 8-channel head coil (RAPID Biomedical GmbH, Rimpar, Germany). Images were obtained with a PMC-enabled EPI sequence, using the XPACE library to dynamically update the imaging gradients[2,3] based on the motion information. The imaging parameters for the EPI time series were: TR = 1 s, TE = 20 ms, and spatial resolution =1 mm^3 isotropic. In phantom study, 3, 7 and 13 slices were obtained for single TR to change slice-by-slice interval and the imaging plane was oriented transversally. An optical tracking system (KinetiCor, HI, USA) was used to collect motion tracking information in six-degrees-of-freedom using a Moiré phase marker as an 80 Hz frame rate. *Phantom study*: A spherical phantom filled with water doped with manganese was moved by a small balloon, which was placed underneath the phantom, applying different air pressure (Kiyohara Optics Inc., Tokyo, Japan) controlled by the "Presentation" software (Neurobehavioral System, CA, USA). The phantom movements were performed as a block design paradigm for 10 volumes of motion following a 10-volume resting interval. Five blocks were acquired in each scan. The paradigm was repeated twice with and without PMC. *Human study*: Three volunteers were included in this study. All experiments were approved by the appropriate institutional review board and written informed consents were obtained from all subjects before each study. The motor task, which involved the up-and-down movement of right arm or leg, was performed as a block design paradigm for 10 or 20 volumes of motion task following 10 or 30 volumes resting interval, respectively. Five blocks were acquired in each scan. The paradigm was repeated twice with and without PMC. *Data analysis*: The analysis was performed by Brain Voyager. A slice scan-time correction and realignment with trilinear and sinc interpolation were applied to all data. A box response function was applied to detect FPAs, which were defined by the ratio of activation voxels to all of the voxels in the phantom. In human study, since the activations due to motor task were expected in the contralateral regions of motor, sensorimotor and supplemental motor cortex, the voxels in ipsilateral regions were considered as FPA. A translation was defined here as the square root of the sum of the squares of the three components, x, y and z, which was measured by the optical tracking system.

RESULTS AND DISCUSSION

In phantom experiments, since there should be no activation, all activations detected were considered as FPA. Figure 1 indicates the percentage of FPA for no PMC and PMC scanned with different number of slices, i.e. duty cycles. The FPA was not dependent on the scan duty cycles and it increased with increasing translation of the phantom (Fig. 1a). With the same range of translation, the percentages of FPA were dramatically reduced with PMC. No differences in the improvement of FPA were found if the retrospective realignment was applied, with may be a small effect on FPA in case of larger translations (Fig. 1b). The results of in vivo experiments are presented in Fig. 2 and show only a very small difference in the percentage of FPA between no PMC and PMC conditions. Also retrospective realignment had no notable effect. The discrepancy between the phantom and in vivo experiments may have several origins. First, in the present study activations in ipsilateral regions of the motor task were considered as FPA, although according so some reports ipsilateral regions may be activated by motor tasks[5]. Further, activations in the contralateral regions were not segmented with gray and white matter masks to account for the fact that activations in white matter are not to be expected, although this issue remains controversial[6].

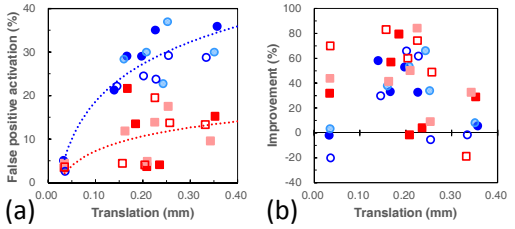

Figure 1: (a) Percentage of false positive activations with no PMC (circles) and PMC (squares) for phantom. Dark, light and white color symbols indicate 13, 7 and 3 slices acquisition, respectively. (b) Improvement of false positive activations by realignment.

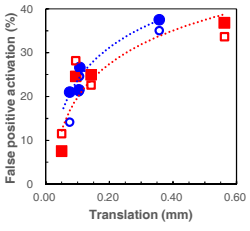

Figure 2: Percentage of false positive activations with no PMC (blue circles) and PMC (red squares) for motor tasks. Opened symbols indicate percentage of false positive activation by realignment.

CONCLUSION

The results in the phantom study suggested that PMC using optical tracking system promises an improvement of motion-induced FPA artifact at a 1-mm isotropic resolution. In a human study only a slight improvement was found, which could be a problem of the present study design and may be improved in future.

REFERENCE

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