High-Resolution Fingersomatotopy at 7T using HGS-Parallel Technique

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Introduction

In a high field MRI, improvements in SNR and image quality are very noticeable, even though there are some drawbacks such as an increased field inhomogeneity and a relatively short T_2^*. For EPI-based methods, these drawbacks are the major challenges in performing an fMRI study. To overcome these problems, researchers tried to modify the imaging sequence or to develop post-processing algorithms, but there still existed residual artifacts and some technical limits. In addition, with EPI technique, it is not easy to increase the spatial resolution due to the short T_2^*. To reduce such problems, we employed the HGS-Parallel technique as an fMRI imaging methods which used the conventional gradient-echo. This sequence is relatively robust to field inhomogeneity and the T_2^* decay than the EPI technique. In this study, by using the HGS-Parallel technique, we performed an fMRI experiment at a 7T MRI for mapping the finger somatosensory area in a high quality and resolution form.

Methods

Since the imaging time of the conventional gradient-echo sequence is generally too slow to perform fMRI, the HGS-Parallel technique [1] combines the sampling strategies of both HGS (Higher-order Generalized Series) [2] and parallel imaging technique for a reduction of scanning time. The HGS technique has the similar sampling scheme to the key-hole imaging, but the data reconstruction for the missing high frequency data is based on the L1-regularization estimation rather than the simple replacement with the fully-sampled reference data, thus it produces more improved results in the reconstructed images. The data acquisition scheme of the HGS-Parallel technique is depicted in Fig. 1d. It acquires data from near the central k-space by taking sampling property of the HGS imaging; it also takes samples at a lower rate than the Nyquist rate by using the parallel imaging property. Let R_{HGS} and R_P be the scan-time saving rates achieved by the HGS and parallel imaging technique, respectively. Then, the HGS-Parallel technique can achieve $R_{HGS} \bullet R_P$-fold saving of the scan time compared to the conventional Fourier imaging as shown in Fig. 1. The reconstruction procedure of the acquired data from this technique is described as follows.

1. For reconstruction, additional reference data were acquired for both HGS and parallel imaging techniques. The reference images were reconstructed using the conventional Fourier transform.
2. Once the data is acquired according to the sampling format of Fig. 1(d), the HGS reconstruction algorithm was applied to this data and then, the result from the HGS reconstruction had the sampling format of Fig. 1(c).
3. The parallel imaging reconstruction algorithm was sequentially applied to the result of the above HGS reconstruction to obtain the final reconstructed images. In this work, SPACE RIP [3] was used as the parallel imaging technique.

During the HGS and parallel MRI reconstruction in our method, total variation and Tikhonov regularization methods were used, respectively. This can make reconstruction more stable and robust.

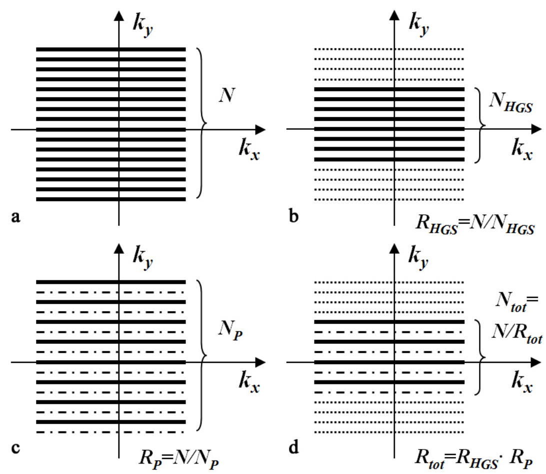


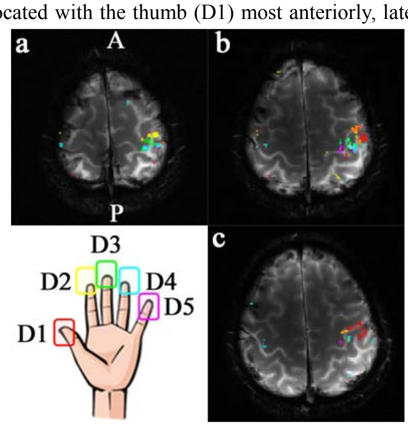
Fig. 1 Sampling schemes for: **(a)** a conventional imaging, **(b)** HGS imaging, **(c)** parallel imaging, and **(d)** the HGS-Parallel technique. Dot and the dot/dash lines: skipped encoding lines by the HGS and parallel imaging techniques, respectively.

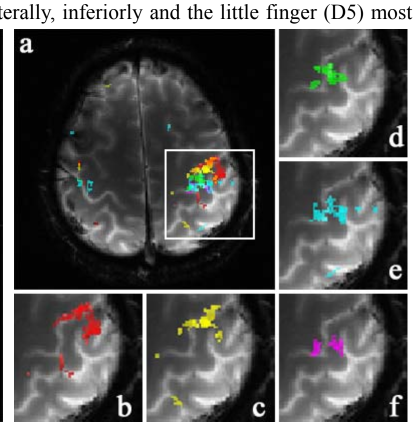
Results

A block-design fingersomatotopy fMRI was performed at a 7T scanner in Gachon Neuroscience Research Institute with an eight-channel phased-array coil. Tactile stimulation was applied to each finger of the left hand, with the continuous forward and backward motion of a commercially available toothbrush. The fMRI data were acquired with following imaging parameters: TR=150ms, TE=20ms, flip angle=10°, 6 slices, FOV=220mm×220mm, acquisition matrix=20×256, R_{HGS}=4 and R_P=3.2. According to the HGS-Parallel reconstruction steps we obtained a series of the reconstructed images with the matrix size of 256×256. The resultant images were analyzed with SPM2. Fig. 2 shows three slices of the functional maps ($P < 0.001$) for 5 fingers of the left hand. The red, yellow, green, cyan and magenta colors stand for the functionally activated area from stimulation of the thumb (D1), index (D2), middle (D3), ring (D4), and little fingers (D5), respectively. As shown in the figure, the right somatosensory cortex was activated for the tactile stimulation of the left fingers. In Fig. 3, we selected a small ROI (a square with white line in Fig. 3a) and magnified this region to look into the difference of the activations for each finger. The functional map of each finger for the selected ROI is displayed in Figs. 3b-f and all these functional results were overlapped onto the one slice (same slice in Fig. 2c) with different colors as shown in Fig. 3a. By comparing those maps, it was clearly observed that the activation position of each finger was slightly different from each other. Analyzing the results from Figs 2 and 3, we could also see that the spatial representation of the functional activation is located with the thumb (D1) most anteriorly, laterally, inferiorly and the little finger (D5) most posteriorly, medially and superiorly. This feature is described with the schematic diagram in Fig. 4. The results showed the consistency with the previously discovered finger somotosensory area [4].

Conclusion

With the HGS-Parallel technique, we could obtain high-resolution (in-plane res.: 0.86mm ×0.86mm, matrix size: 256×256) functional maps for the fingersomatotopy at a 7T MRI.





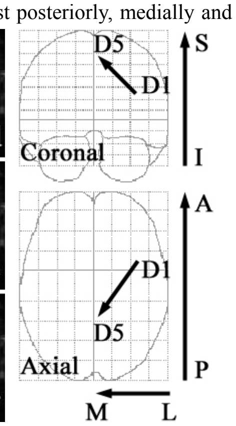


Fig. 2 (Left) Functional maps of 3 slices from superior to inferior **(a~c)** direction. **Fig. 3 (Middle)** Functional maps for **(a)** whole fingers and **(b~f)** each finger from D1 to D5. **Fig. 4 (Right)** Schematic diagram for the functional distribution of each finger. S, I, A, P, M and L represent superior, inferior, anterior, posterior, medial and lateral, respectively.

References

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