The effects of coil compression on simultaneous multislice and conventional fMRI

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PURPOSE: Simultaneous multislice (SMS) imaging is an increasingly popular parallel imaging method for accelerating fMRI, but typically requires array coils with many coils, and therefore much storage space and computation time. Here, we investigate the effects that coil compression can have on functional activation for both SMS and conventional fMRI. Although SMS imaging has been demonstrated using Cartesian trajectories [1], it can also benefit from the susceptibility properties of efficient non-Cartesian trajectories. We use a concentric ring trajectory to enable better SMS GRAPPA reconstruction while still benefitting from the susceptibility signal recovery advantages provided by the similar spiral-in sampling pattern.

METHODS: Three-minute visual and motor stimulus scans were performed on subjects using both SMS fMRI and non-SMS (conventional) fMRI using a 32-channel head coil. Both scans used a concentric ring k_x-k_y trajectory developed using principles from [2]. The SMS scan used a CAIPI-like blipped k_z trajectory [1]. Each SMS acquisition consisted of three simultaneous 3 mm thick slices, with a 13-slice gap between the simultaneous slices. Thirteen acquisitions were performed per time frame, resulting in a total of 39 slices per frame. For the conventional scan, 39 slices were separately acquired at locations matching those of the SMS scan. The conventional scan used a TR three times the SMS scan's TR of 663 ms. The calibration and field map scans for SMS were acquired with a TR of 663 ms, and consisted of separately acquired slices at the same locations of the SMS scan. The Ernst angle for gray matter was used for all flip angles.

Coils were compressed using a Singular Value Decomposition (SVD) from 32 to 24, 16, and 10 coils for both SMS and conventional scans, and additionally to 5, 4, 3, 2, and 1 for the conventional scan. Ten time frames taken from the middle of each 3-minute scan were used to compute the compression matrices. For SMS, 13 compression matrices were used to compress each of the 13 acquisitions per time frame. For the conventional scan, 39 matrices were used, 1 for each slice. The SMS scan used the same set of matrices for each time frame, as did the conventional scan. The SMS calibration scan, which necessarily had slices acquired individually, used the same set of 13 compression matrices as the SMS scan.

For reconstruction, both non-Cartesian GRAPPA [3] and SENSE [4] methods were used for the same SMS scan. The GRAPPA reconstruction used 3 radial sectors and 16 angular sectors to produce separated slices. The SENSE data, the GRAPPA-separated slices, and the conventional scan were reconstructed using conjugate gradient with finite difference regularization, field map corrections, and NUFFTs [5].

RESULTS: In Figures 1 and 2, activation overlays are shown for a selected visual cortex slice for different numbers of virtual coils, and for the different acquisition types and reconstruction methods. As can be seen, the areas of activation changed very little with compression factor, except for minor reductions of activation for greater compression. Figure 3 shows a plot of activated voxel counts in a mask versus number of virtual coils used. The mask covered visual cortex areas in 14 inferior slices and motor cortex areas in 10 superior slices.

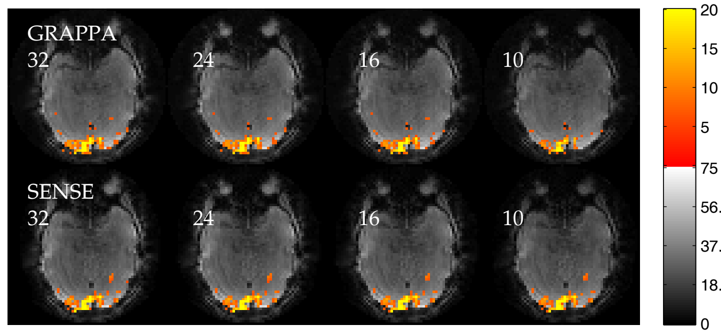

Fig 1: Activation overlays (t-scores) for one slice of the SMS scan. Columns, from left to right: 32 coils (no compression), 24 virtual coils, 16 virtual coils, and 10 virtual coils. Top row: SMS GRAPPA. Bottom row: SMS SENSE. Threshold of t = 6.

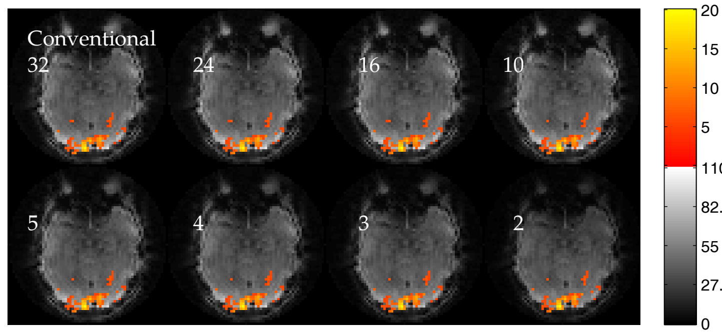

Fig 2: Activation overlays (t-scores) for one slice of the conventional scan. Top row from left to right: 32 coils (no compression), 24, 16, and 10 virtual coils. Bottom row from left to right: 5, 4, 3, and 2 virtual coils. Threshold of t = 4.91.

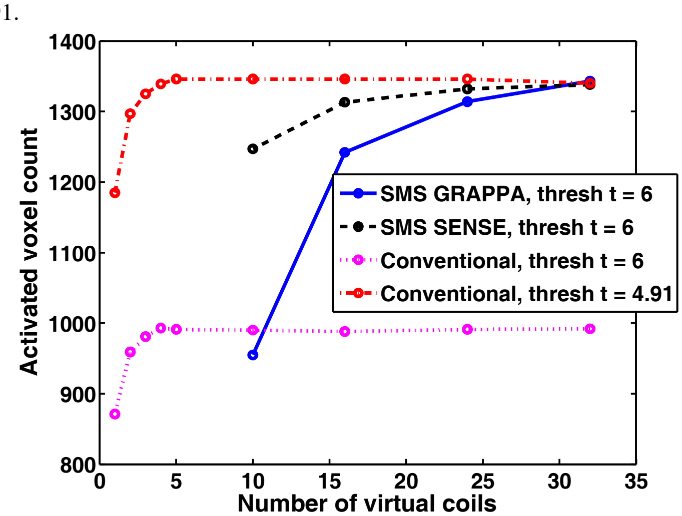

Fig 3: Activation counts in a visual and motor cortex masked region. T-score thresholds are indicated in the legend.

CONCLUSION: SVD coil compression is an effective way to greatly reduce raw data storage needs and computation time for both SMS fMRI and conventional fMRI, without an appreciable decrease in activation quality. As expected and as shown in Figure 3, conventional fMRI is comparably more compressible than SMS fMRI; fewer conventional virtual coils are needed before activation begins to suffer. Conventional fMRI activation quality only begins to decrease with compression down to 4 virtual coils, while SMS fMRI activation begins to decrease with 16 virtual coils. Additionally, as shown in Figures 1 and 2, the locations of activated areas are very consistent with various degrees of coil compression for both SMS and conventional fMRI.

REFERENCES: [1] Setsompop et al. 2012. Magn Reson Med. 67:1210. [2] Pipe et al. 2014. Magn Reson Med. 71:278. [3] Heidemann et al. 2006. Magn Reson Med. 56:317. [4] Pruessmann et al. 1999. Magn Reson Med. 42:952. [5] Fessler et al. 2003. IEEE T-SP. 51:560.