Simultaneous multi-slice (SMS) accelerated EPI navigators for prospective motion correction in the brain

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TARGET AUDIENCE: Clinicians and researchers interested in prospective motion corrected neuroimaging.

PURPOSE: EPI navigators have previously been proposed for prospective motion corrected anatomical [1] and functional [2,3] neuroimaging. One of the limitations of the EPI navigator approach is the additional time required to collect the navigator images, which ranges from 170 to 300 msec depending on spatial resolution and coverage. This makes it difficult to insert them into sequences without any dead time (e.g. 3D FLASH). EPI navigators are also susceptible to motion during navigator acquisition. Simultaneous multi-slice (SMS) EPI with blipped CAIPI [4] makes it feasible to acquire multiple slices simultaneously, resulting in significantly higher temporal resolution for functional imaging studies. The goal of this work was to use SMS acceleration to speed up the acquisition of EPI navigators. Validation studies were performed in phantoms and in-vivo to demonstrate that SMS accelerated navigators can be used to accurately detect motion over a range of motion values. Furthermore, prospective motion correction was demonstrated by adding SMS navigators into an inversion prepared gradient echo (MPRAGE) sequence.

METHODS: 2d SMS EPI navigator images were acquired on a 3T MAGNETOM Skyra scanner with the following parameters: FOV: 256x256x80 mm^3, matrix: 32x32x10 (10 slices with 8 mm thickness), spatial resolution: 8x8x8mm^3, flip angle = 10°, 5 slices excited simultaneously (SMS5), relative shift between slices = FOV/4. The acquisition time for each slice group consisting of 5 slices was 14 msec, leading to a total acquisition time of 28 ms. for the entire navigator volume (2 shots of 5 slices each). **Phantom imaging:** A structured resolution phantom was imaged in 3 positions with a high spatial resolution (1mm^3), 3d FLASH and a SMS5 navigator sequence. These volumes were then co-registered and motion estimates derived from them were compared. **Volunteer imaging**: 5 healthy volunteers were scanned with a 2.5 min long SMS navigator sequence during which subjects were instructed to freely move their heads. The navigator images were retrospectively registered to derive a range of motion estimates within which SMS navigators are expected to function accurately. In addition, to demonstrate prospective motion correction, SMS navigators were inserted into the TI gap of a MPRAGE sequence. During each TR a SMS navigator volume was acquired. The entire navigator processing and reconstruction including slice GRAPPA based unaliasing, registration, feedback to scanner, and field-of-view update was completed in ~ 100 ms. A non-motion corrected MPRAGE sequence was also acquired for comparison purposes. To evaluate the efficacy of motion correction, subjects were deliberately instructed to follow a predefined motion protocol during both scans.

RESULTS: Fig 1 shows sample SMS EPI navigator images acquired in 2 subjects. In spite of the high SMS acceleration good image quality is seen without any residual slice leakage. Although the slice GRAPPA reconstruction indirectly uses spatially dependent coil sensitivity information to separate the slices, good reconstruction fidelity was observed over a range of head positions in all 5 subjects (Fig 2). Fig 3 shows results of the phantom experiment. Motion estimates derived from the SMS navigator images (8mm^3 resolution) show excellent correlation with those derived from the 3d FLASH images (1mm^3 resolution). Fig. 4 shows results of prospective motion correction in a subject. The scan with prospective motion correction (left) shows significantly improved image quality compared with the non-corrected scan (right).

DISCUSSION AND CONCLUSION: We demonstrated a SMS EPI navigator technique which acquires a low spatial resolution (8x8x8mm^3) brain volume in ~28 msec. Preliminary validation studies show that in spite of the low spatial resolution, accurate motion estimates can be derived for a range of phantom and head motions. The efficacy of using this ultra-fast SMS navigator for prospective motion correction was shown by inserting it into a MPRAGE sequence. Future work will focus on further validation studies and inserting the SMS navigator into sequences without any dead time (e.g. T2 tse imaging).

REFERENCES: [1] Tisdall MRM 68:389-99. [2] Bhat ISMRM 2012, #113. [3] Thesen MRM 44:457-65. [4] Setsompop MRM 67:1210-24.

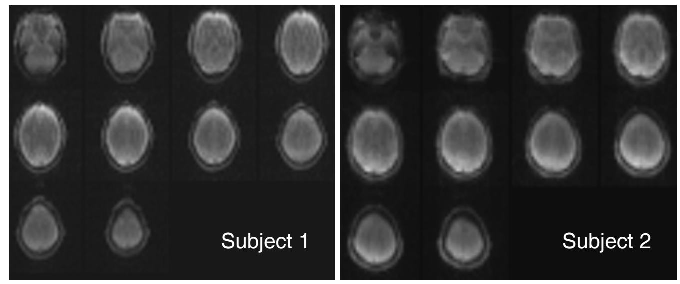

Fig 1: Sample EPI navigator images acquired in 28 msec (SMS5)

Rotation (deg)				Translation (mm)			
	x	y	z		x	y	z
min	-8.6	-8.4	-3.3	min	-5.3	-11.4	-5.4
max	5.4	4.3	1.1	max	4.1	3.3	12.4

Fig 2: Range of motion values derived from SMS navigator images acquired during head motion in 5 healthy volunteers

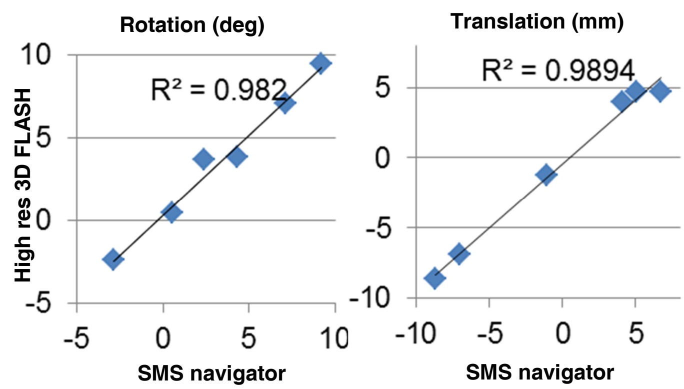

Fig 3: Comparison between motion estimates in a resolution phantom derived from registration between high resolution (1mm^3) 3D FLASH images (Y axis) and SMS navigator images (X axis).

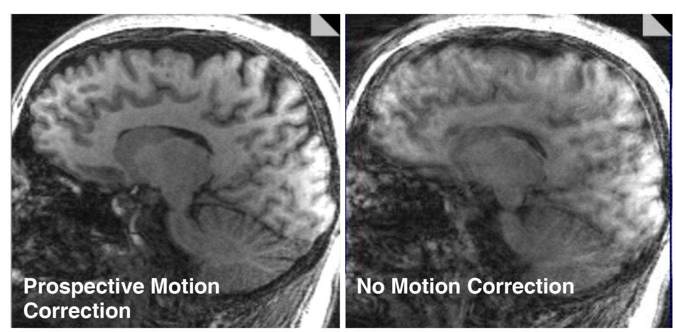

Fig 4: Results of prospective motion correction in a healthy volunteer