Motion-induced Field Change in the Brain

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Introduction

Motion is a major source of artifact in MRI[1-4]. Head motion induces B_0 field change in the brain as a function of the subject's global susceptibility distribution. The severity of this issue increases with the field strength and echo time (TE).

In this study, the pattern and magnitude of the motion-induced field change in the brain were investigated. This field change arises from two factors:

- A change due to motion of the head in the inhomogeneous (stationary) fields from the magnet (and shims) and the magnetization of the non-moving torso
- A change due to the (moving) magnetization of the head

Methods

- Five healthy subjects were scanned on a Siemens 7 T MRI scanner (with a home-built birdcage transceive head coil[5]) and one subject on a Siemens 3 T MRI scanner (with a vendor-provided birdcage transceive body coil and a Nova 32-channel receive head coil).
- The subjects were instructed to move their heads to different positions. For each position, a set of 2D multi-echo GRE data was acquired with an isotropic resolution of 2 mm and FOV of 240x180x168 mm^3.
- Head position relative to the first acquired volume ('Neutral') was determined based on co-registration of the GRE magnitude data. B_0 maps were calculated based on the unwrapped inter-echo phase difference of the GRE data.
- For each experiment session, the background field including the magnet field and the shim field was measured with a spherical phantom.
- Background-corrected field distortion in the brain was calculated by subtracting the background field from the measured B_0 field.
- The effect of this background-corrected, motion-induced field distortion was evaluated in a simulation by applying the field distortion to two central read-out lines in the k-space of a 128-by-128 image using a GRE scheme with an effective TE of 25 ms.
- To simulate the field distortion due to head motion, a two-compartment (tissue: -9 ppm and air: 0.36 ppm) susceptibility model of the subject in the 3 T experiment was generated based on GRE scans covering the subject's head, neck and torso with a total length of 50 cm in the z-direction. (This was not feasible at 7 T due to the lack of a body coil.)
- In the simulation model, regions including paranasal sinuses were assigned with the susceptibility value of air; regions of lung and nasal pathway were treated as mixed air and tissue with ratios of 8:2 and 7:3, respectively.

Results

- Result of one example subject at 7 T (similar magnitude and pattern of field shift were observed in other four subjects)

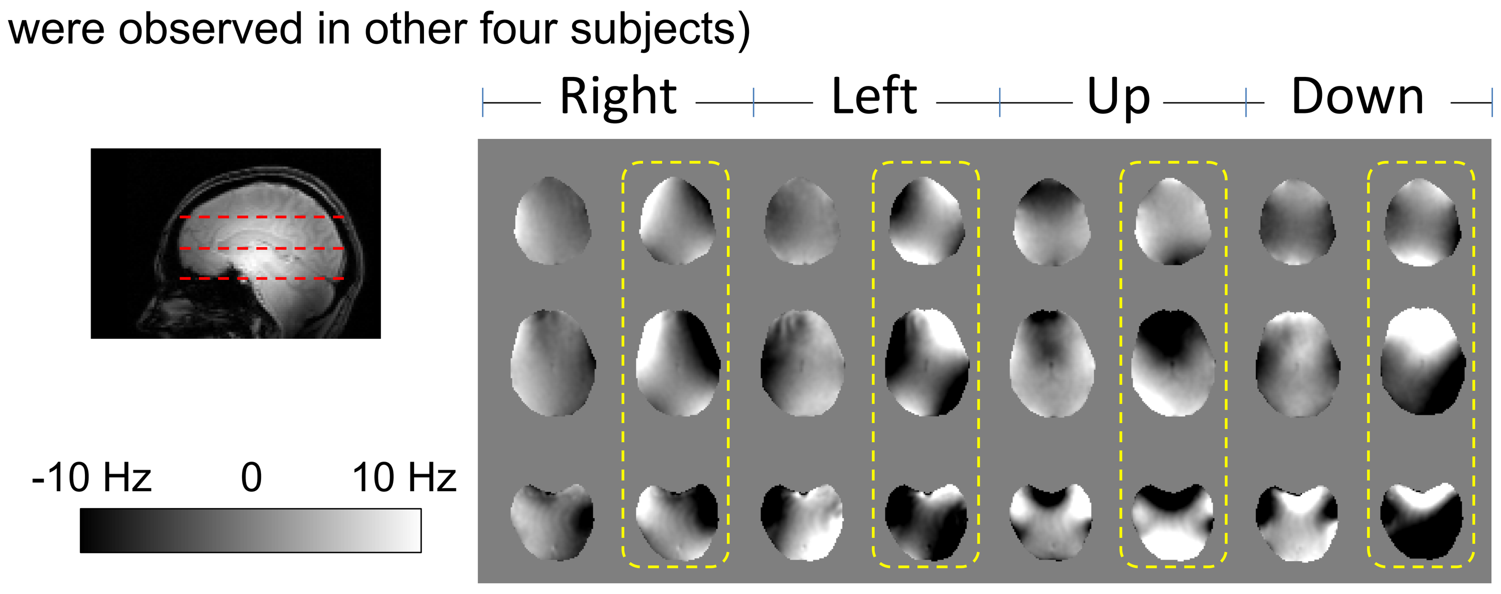

Figure 1 Motion-induced field changes in three slices of one volunteer in four positions relative to 'Neutral' at 7 T. Motion parameters are summarized in Table I. The subject moved his/her head by turning it to the 'right' or 'left' or tilting it 'up' or 'down'. Yellow dash box indicates field change *without* background-field correction.

Table I Motion parameters of the data shown in Fig. 1

	Rotation*/º			Translation/mm		
	x**	y	z	x	y	z
Right	-0.7	-1.3	-7.2	6.6	-1.4	-0.3
Left	1.7	-0.6	8.7	-5.0	0.5	-1.2
Up	-5.2	-0.8	2.1	-0.5	-2.6	-4.2
Down	4.9	-1.5	3.0	1.2	0.6	0.6

*: The center of the rotation is on the center of the FOV in all three directions.
**: The positive directions of x, y and z axes are towards the left, posterior and head direction of the subject, respectively.

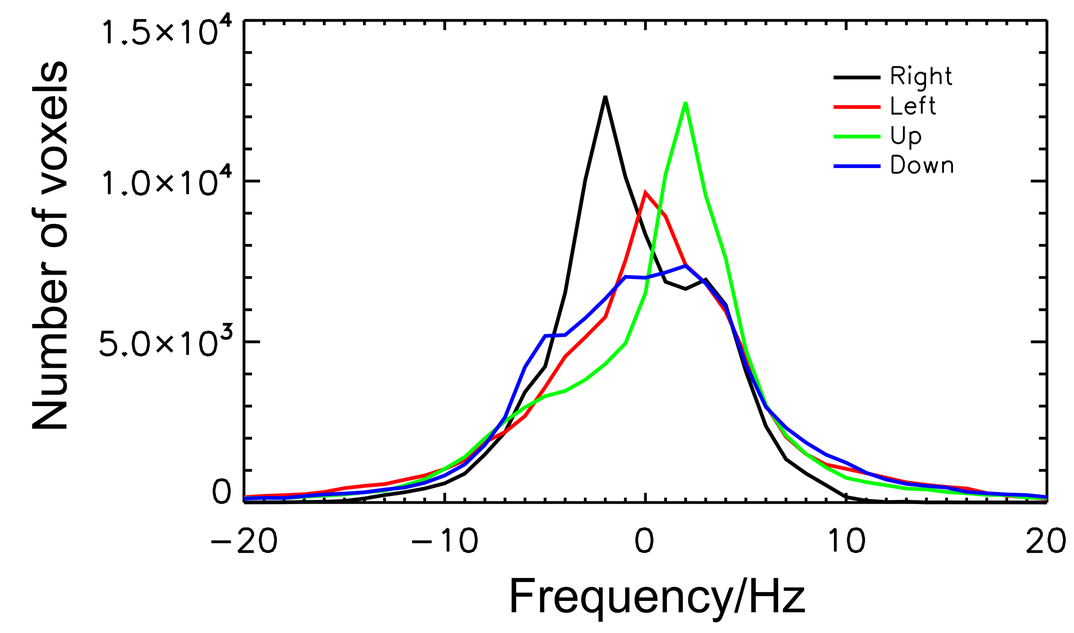

Figure 2 Histogram of field change with background-field correction in the brain

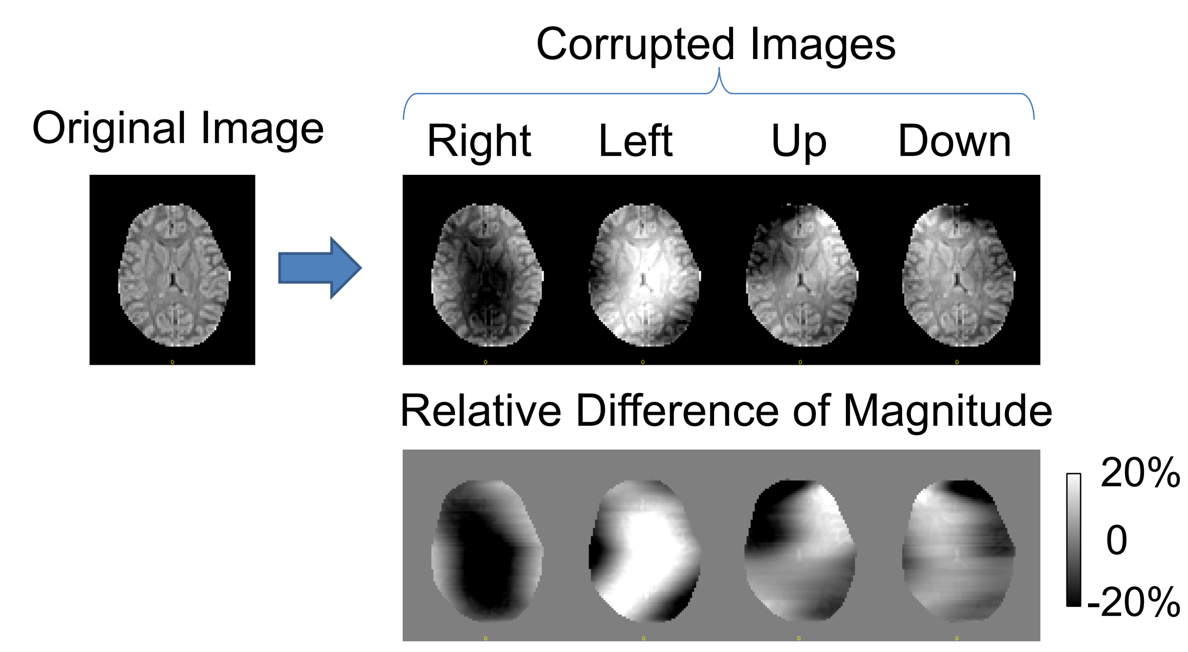

Figure 3 Impact of the observed field change on a GRE simulation (TE=25 ms) of which the two central lines of data in the k-space were affected by the field change

- Result of the second subject at 3 T

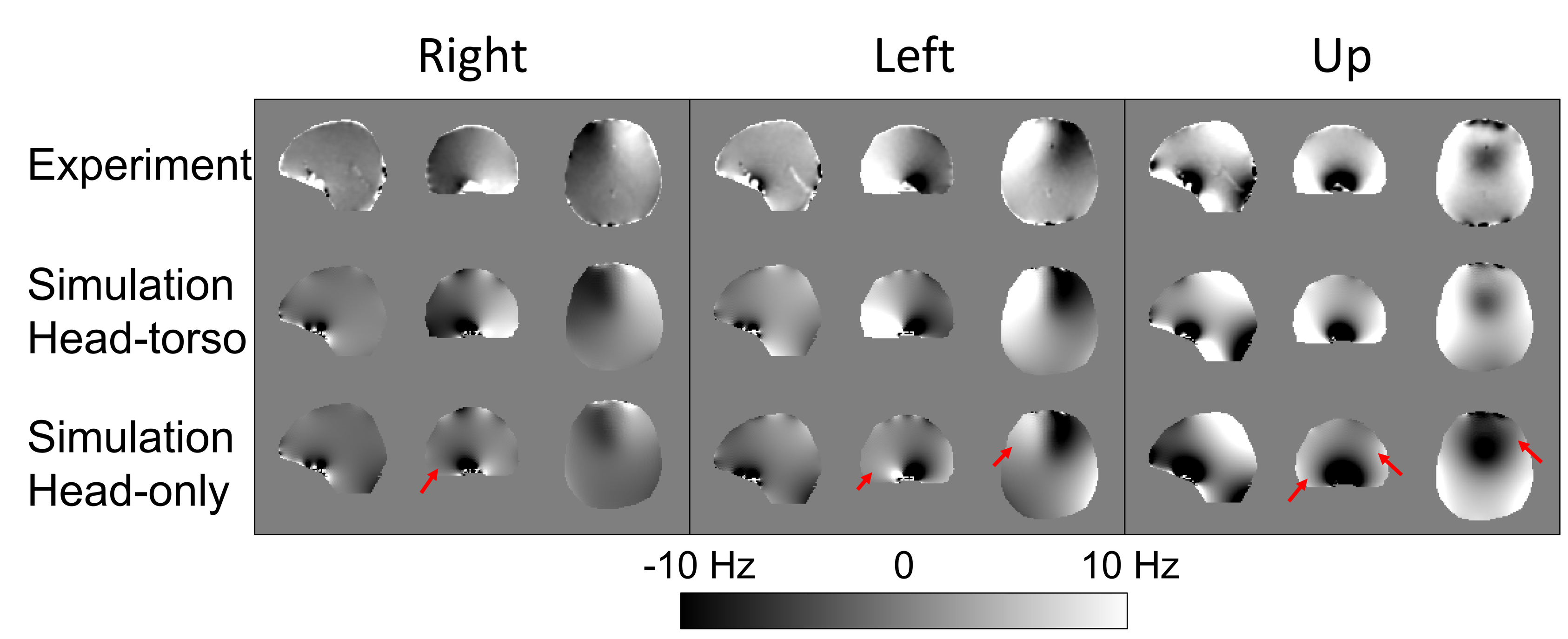

Figure 4 Measured field change in the brain at 3 T with background field correction in comparison with simulated field changes based on the head-torso and the head-only model, respectively. Significant difference as marked by arrows can be observed in the simulation result based on the head-only model compared with the experiment data.

Table II Motion parameters of the data shown in Fig. 4

	Rotation/º			Translation/mm		
	x	y	z	x	y	z
Right	-0.6	-2.1	-10.6	3.5	-1.0	0.0
Left	-2.5	3.7	7.3	-3.0	-0.2	-1.5
Up	-7.3	1.1	0.5	-1.0	-1.2	4.0

Conclusions

- Small head motion (<10 mm translation; <10º rotation) can induce significant B_0 field change in the brain with a magnitude of up to 0.1 ppm and irregular patterns, which can lead to considerable artifacts in susceptibility-weighted acquisitions.
- The stationary field from the torso contributes significantly to the motion-induced field change in the brain.

References

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