Characterisation of Motion-Induced Field Distortions in Spectroscopic Imaging With Prospective Motion Correction

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Introduction

The long scan duration makes spectroscopic imaging (SI) experiments particularly susceptible to motion-induced artifacts. Prospective motion correction based on an optical tracking system [1] has recently been proposed for 2D SI in the human brain [2]. Additionally, retrospective phase correction using the interleaved reference scan (IRS) method has been applied for the correction of motion-induced frequency drifts [2, 3]. The method has been validated for the correction of axial head rotations during the scan, which implies mainly in-plane motion when a transverse SI slice is used. In this work, an SI experiment with through-plane head motion was performed, using prospective motion correction and retrospective phase correction. Furthermore, the motion-induced shim changes in the SI slice were characterized to evaluate the potential of real-time shimming for motion-corrected SI measurements.

Materials and Methods

Prospective motion correction with inter-scan position locking was implemented into a PRESS-based SI sequence on a Magnetom Trio 3T system (Siemens Healthcare, Germany) equipped with a phased array head coil for signal reception [3]. Motion was detected with a stereoscopic tracking system (ARTrack3, Advanced Realtime Tracking GmbH, Germany) reporting positions of a mouth piece fitted with four retro-reflective spheres [1]. An *in vivo* SI experiment with IRS was performed on a healthy subject (transverse slice, slice thickness = 15 mm, FOV = 20 cm, res = 16 × 16, TR = 2.5 s, TE = 30 ms, OVS with 8 slabs, scan duration ≈ 11 min). Then the subject was asked to tilt his head forward and the SI experiment was repeated for the new head position, applying motion correction and position locking with respect to the initial head position, but keeping the shim setting of the first SI experiment. Afterwards the SI experiment was repeated with prior reshimming. The new as well as the old shim settings were logged for comparison.

Results

Figure 1 shows the setup for the SI experiments as well as the head movement performed by the subject in between scans. The red boxes indicate the origin of the SI spectra shown in Fig. 2. Spectra from the occipital cortex acquired with shim preparation in the final (tilted) head position (Fig. 2b) show no significant spectral degradation compared to the spectra acquired in the initial head position (Fig. 2a). In contrast, the spectra acquired without reshimming after motion (Fig. 2c) are degraded by line broadening and a strong frequency shift of 0.5 ppm. The frequency shift can be corrected with IRS phase correction, albeit at the expense of baseline distortions (Fig. 2d). The spectra from the frontal cortex, which was more strongly affected by subject motion than the posterior part of the brain, are completely corrupted (not shown). A comparison of the shim settings for the initial and the final head position yielded a strong change in the second-order Z2 component, but only mild alterations for the other first- and second-order shim terms.

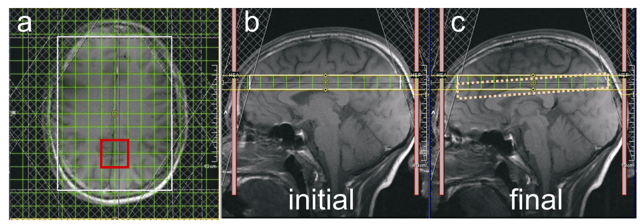

Fig. 1: a) Setup for the SI experiment with the white box representing the PRESS (shim) volume and the red box indicating the region of interest in the occipital cortex. Images from the initial and final head position are shown in b) and c), with the initial SI setup superimposed and the motion-tracked SI slice indicated with a dotted line.

Discussion

Prospective motion correction with inter-scan position locking not only renders localized MRS experiments more robust, but also enables a precise characterisation of the motion-induced field distortions in the volume of interest. Compared to motion-corrected SI experiments with predominantly in-plane motion [3], through-plane motion can severely impair the spectral quality since the shim setting in this direction is more local than for the in-plane dimensions. In single voxel experiments with small edge lengths, considerable field changes may therefore be observed in all three directions. The largest susceptibility gradients are typically found close to the nasal cavities in the frontal cortex, exacerbating motion-induced spectral degradation in this region, particularly for motion in the z-direction. This agrees with the observation of large frequency drifts for motion-corrected single voxel spectroscopy in the frontal cortex [4]. Which shim components are affected also depends on the kind of motion. As a displacement of second-order polynomials can be expressed in terms of additional zero- and first-order terms only, translational motion of a given susceptibility distribution in a homogeneous field can be compensated with a linear shim update. In contrast, rotational motion changes the orientation of the susceptibility distribution with respect to the magnetic field, which can give rise to higher order field distortions. That was also the case in this work where head motion mainly consisted of a rotation around a sagittal axis and therefore the Z2 component became the dominant correction term in the reshim. Spectral line broadening in MRS data through zeroth-order field drifts can readily be prevented with the IRS method while a correction of higher order field changes would require a real-time shim update. A correction of second-order shim components is beyond the capabilities of currently available clinical MR systems, but at least linear shim components might be updated with an interleaved acquisition of navigators [5, 6]. In conclusion, results show that real-time shimming would be essential for robust motion-corrected SI experiments.

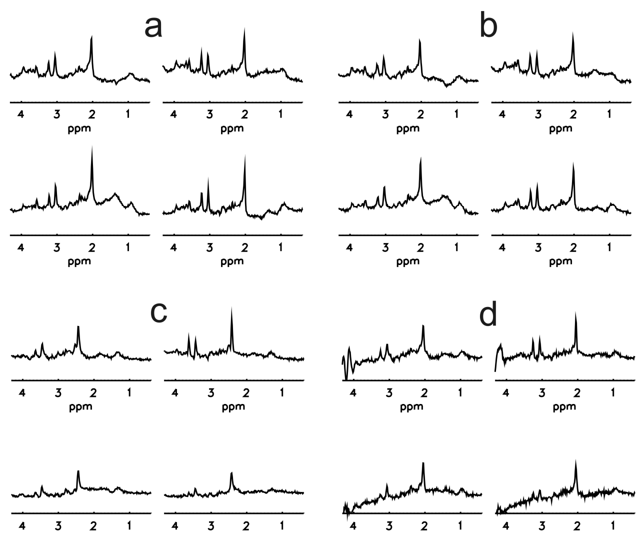

Fig. 2: Spectra from the occipital cortex: acquired before (a) and after (b) head motion with shimming activated as well as acquired after head motion, but keeping the shim setting of the first SI scan, with (c) and without (d) IRS correction.

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References

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