Exploring ECCENTRIC sampling variants for accelerated high-resolution MRSI

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BACKGROUND

The acquisition of high-resolution MRSI is generally prohibitively long and strategies for accelerating this process are often limited by the capabilities of the magnetic field gradient system[1]. ECCENTRIC[2,3] is a new MRSI sampling strategy that was designed to address both problems by combining actual random k-space under-sampling for compressed-sensing (CS) and trajectories with low demand of gradient slew-rate. By design, ECCENTRIC acquisition are characterized by: the circle radius (CR), CS acceleration factor (CS) (See Fig.1 for illustration). The precise impact of these parameters on the measured signal-to-noise ratio (SNR) and the quality of the reconstructed metabolite maps should to be evaluated.

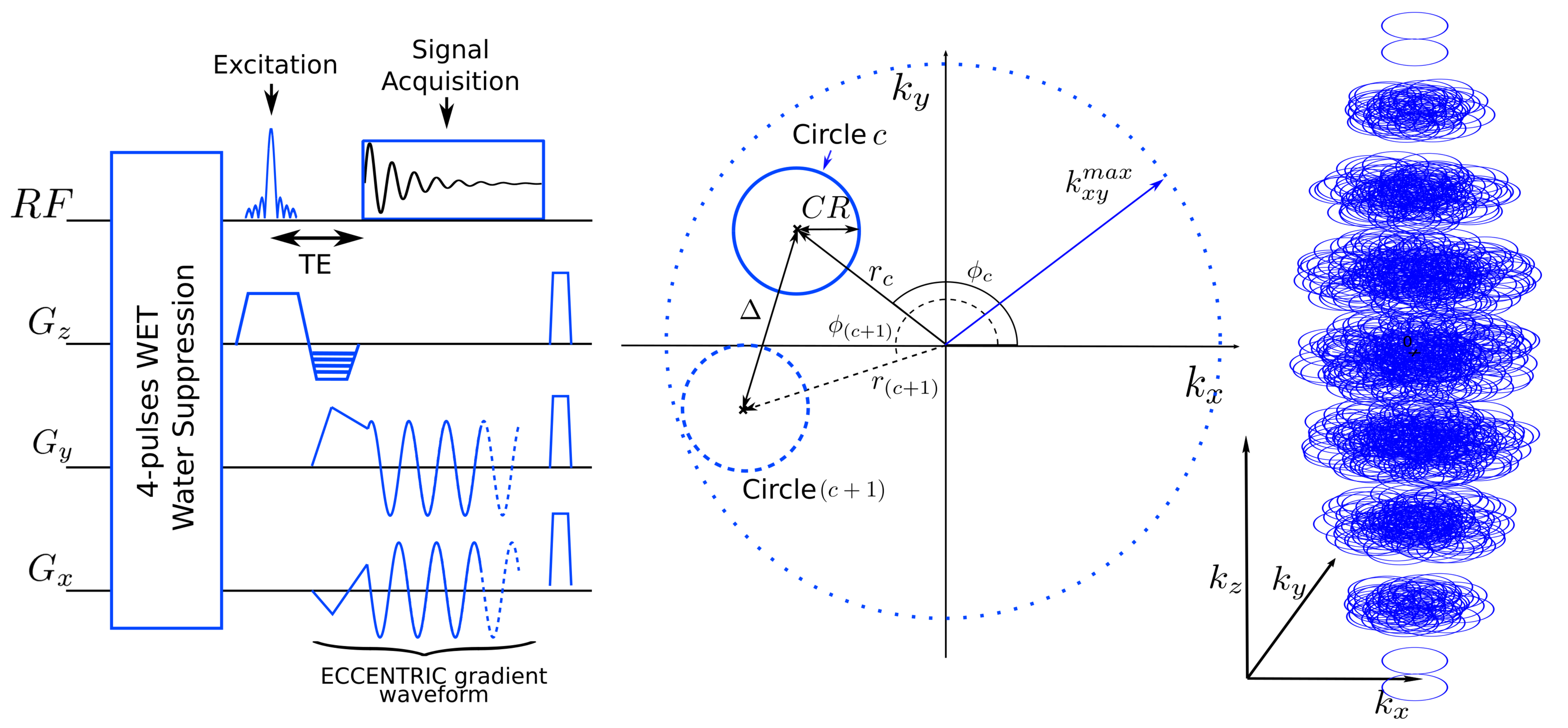
AIMS

Investigate the effect of ECCENTRIC trajectory parameterization on the resulting high-resolution accelerated metabolite mapping.

METHODS

3D FID-MRSI ECCENTRIC data were acquired at a 3T MRI Prisma (Siemens), 0.8ms TE, 45° excitation flip-angle and 470ms TR, 1250Hz spectral bandwidth on a volunteer. 3 MRSI acquisiitons with the same TA = 14min and 5mm isotropic resolution were acquired with different ECCENTRIC circle radii and CS acceleration factors: (CR = k_{max}/4, CS = 1), (CR = k_{max}/8, CS = 2) and (CR = k_{max}/16, CS = 4) (See Fig.2). For ECCENTRIC sampling, the number of randomly positioned circles is given by $N_c = \pi k_{max}^2/(2 \cdot CR \cdot CS)$. For comparison, equivalent Cartesian FID-MRSI with full elliptical sampling is acquired with TA = 98min.

Fig.1: 3D FID-MRSI with ECCENTRIC



Acquisition data were reconstructed with a CS-SENSE-LowRank model WITH TGV regularization[4] adapted to ECCENTRIC encoding:

Spatial Comp. Spectral Comp. TGV Spatial regularization
Acquired data

$$\arg\min_{\mathbf{U},\mathbf{V}} \|\mathbf{s} - \mathcal{FSB}\{\mathbf{UV}\}\|_2^2 + \lambda \sum_{c=1}^{N_C} \mathrm{TGV}^2\{U_c\}$$

B_0 inhomogeneity
Coil Sensitivity
ECCENTRIC encoding

[1] Bogner W, Otazo R, Henning A. Accelerated MR spectroscopic imaging—a review of current and emerging techniques. NMR Biomed. 2021;34(5). doi:10.1002/nbm.4314

[2] Klauser A, et al. ECcentric Circle ENcoding TRajectorIes for Compressed-sensing (ECCENTRIC): A fully random non-Cartesian sparse k-space sampled MRSI at 7 Tesla. ISMRM Annu Meet. 2021 #0835.

[3] Klauser A, et al. Whole-brain high-resolution MRSI at 7T with non-Cartesian FID-ECCENTRIC in glioma patients. ISMRM Annu Meet. 2022 #4799.

[4] Klauser A, Klauser P, Grouiller F, Courvoisier S, Lazeyras F. Whole-brain high-resolution metabolite mapping with 3D compressed-sensing SENSE low-rank 1 H FID-MRSI. NMR Biomed. 2022;35(1). doi:10.1002/nbm.4615

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RESULTS

Fig.2: ECCENTRIC sampling for various CR and CS (middle k_z partition)

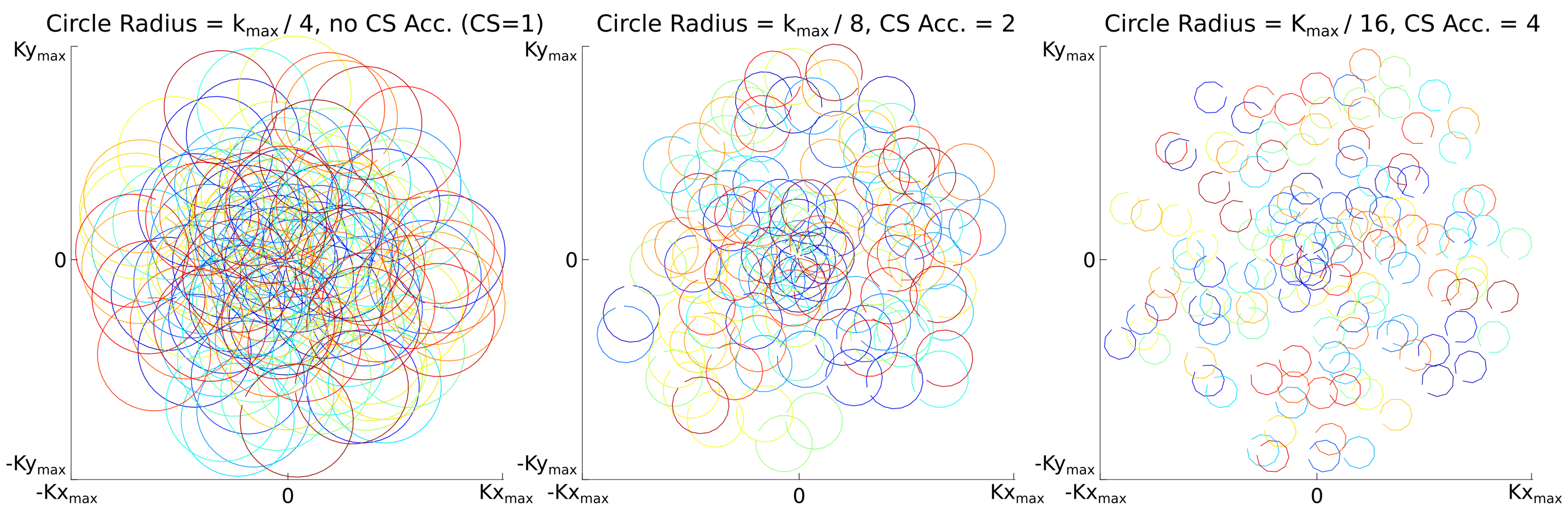
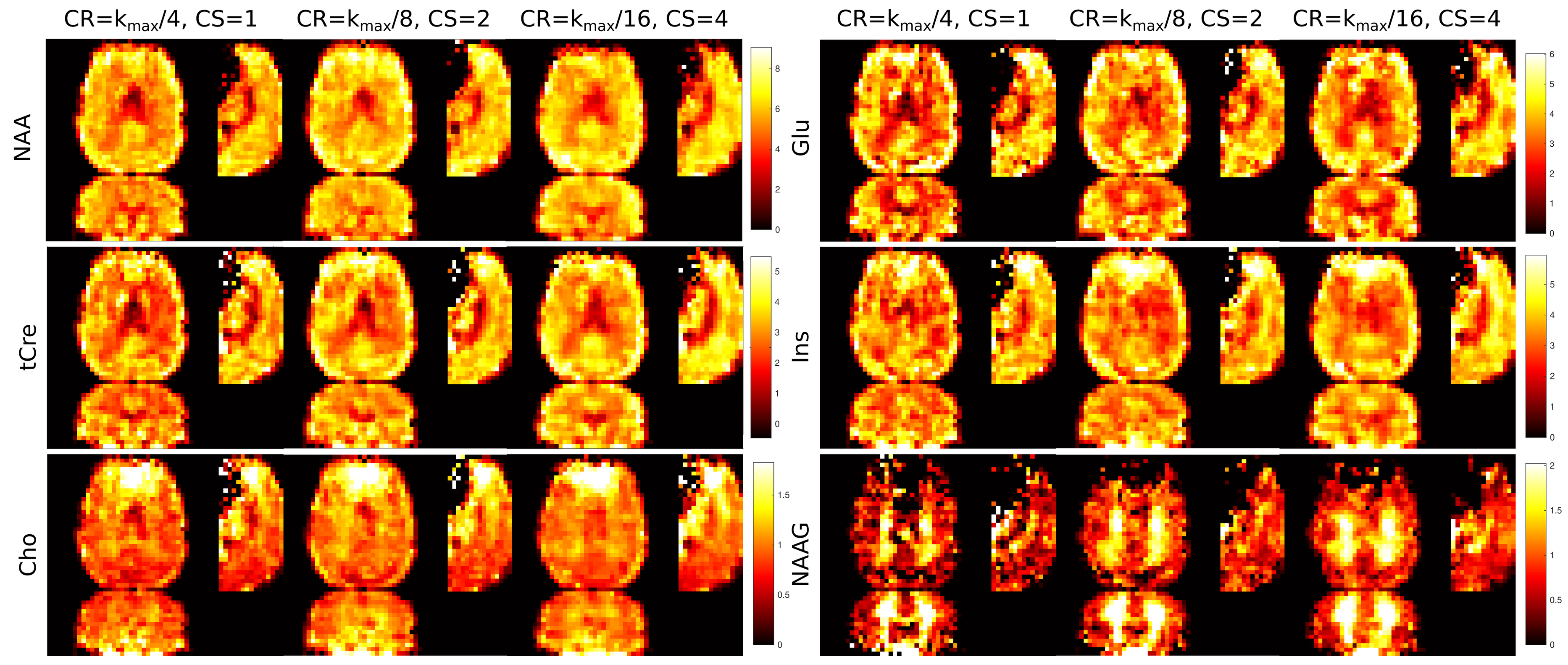
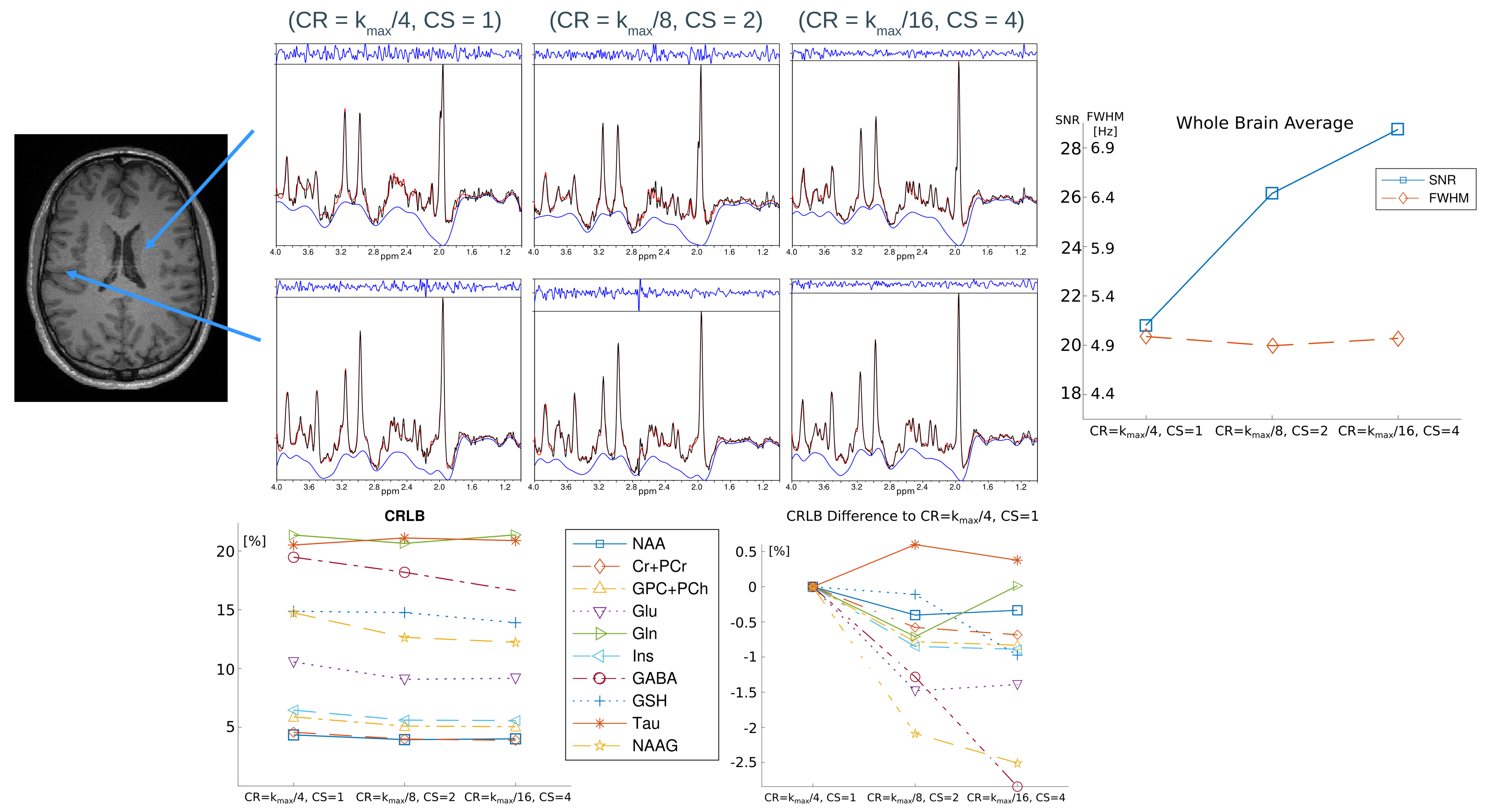


Fig.3: Resulting metabolite mappings for various CR and CS





Decreasing CR while increasing CS affects the sharpness of the metabolite mapping (due to Compress Sensing acceleration) with marked blurring for CS=4. Nevertheless, decreasing CR results in a notable gain in SNR (+~30% , +~40% due to the extended dwell-time $\propto SNR^2$) and reduction of CRLB in low signal metabolites. Among the 3 parameter sets, (CR = k_{max}/8, CS = 2) showed the best performance with a marked increase in SNR and little visible blurring on metabolite maps.

CONCLUSION

MRSI acquisition encoded with 3D ECCENTRIC can be optimized by reducing the circle radius (CR) and thus increasing the dwell time. The results show a better quantification of low signal metabolite (Glu, NAAG, Ins, Gln,…) with lower CRLB, and qualitatively improved metabolite mapping, consecutive to the gain in SNR. However, the reduction in CR required a higher CS acceleration for an equivalent acquisition time, which may cause blurring in metabolite maps. More generally, we demonstrated that ECCENTRIC encoding should not be performed with maximum CR (limited by slew rate) but can be optimized by adjusting of CR and CS, for a given spatial resolution and TA.

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