Impact of Image Acquisition on Voxel-Based Morphometry for Investigating Age-Related Structural Brain Changes

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Target Audience: Researchers interested in VBM, structural brain imaging, or aging; sequence developers interested in 3D T_1-weighted MRI.

Purpose: Voxel-based morphometry (VBM) is increasingly used to investigate structural brain changes. Generally, VBM studies may differ in the employed MRI hardware, pulse sequence, or acquisition parameters as well as in the specific image-processing strategy. Recent research suggests that such differences have an influence on the sensitivity of VBM analyses.[1] Purpose of the current study was to evaluate the impact of the image acquisition strategy on VBM results with specific emphasis on the influence of the specific RF coil, imaging pulse sequence, and image resolution.

Methods: T_1-weighted MRI was performed at 3 T on a Siemens MAGNETOM Verio in 36 healthy volunteers, grouped into young (22.3±1.1 y, 6 female), middle-aged (46.6±1.4 y, 6 female), and elderly (71.8±1.9 y, 6 female) to study age-related gray-matter (GM) changes with VBM. Six datasets were acquired per subject with the 12-channel matrix coil and a 32-channel array, MP-RAGE and MP2RAGE with similar parameters as recommended by the ADNI consortium[2] and Marques et al.[3], respectively, and with nominal isotropic resolutions of 0.8 and 1 mm. All scans lasted for approx. 9:30 min. Images were segmented using SPM8 and default parameters for MP-RAGE, whereas MP2RAGE images were segmented without additional software-driven bias-field correction. Images then were registered to a study-specific template using the DARTEL-VBM approach. Modulated and smoothed (8mm FWHM) GM segments were statistically assessed using a flexible factorial design with the total intracranial volume as covariate in SPM8 and a threshold of 10% GM-tissue probability. Clusters were obtained using a voxel threshold of $p<0.001$; color-coded clusters shown in the Figures correspond to $p<0.05$ FWE corrected for non-stationarity. Paired t-tests comparing data from the same subject acquired with different protocols were computed to investigate the rate of false-positive GM density differences. Interaction tests yielded information on the sensitivity of a specific protocol for detecting aging effects. SNR estimates for MP2RAGE were obtained by consideration of error propagation.

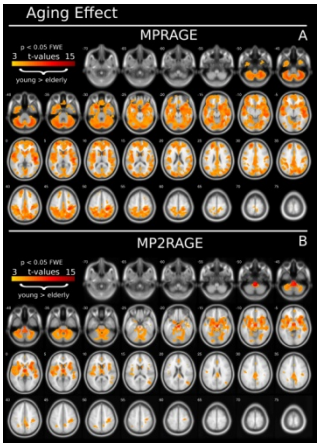

Fig. 1. t-tests of age effect (young/elderly) in acquisitions (32ch. coil, 1mm res.) with (A) MP-RAGE and (B) MP2RAGE.

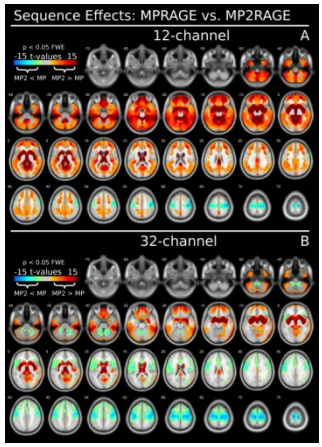

Fig. 2. Paired t-test (MP-RAGE vs. MP2RAGE) for (A) the 12-channel and (B) the 32-channel coil.

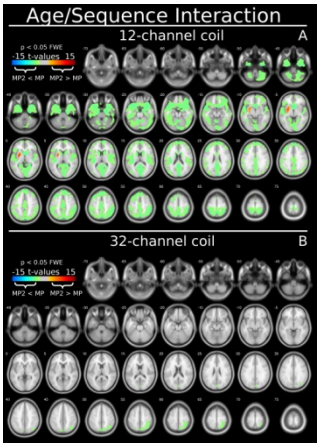

Fig. 3. Interactions effect of age and MRI sequence in acquisi-tions with (A) the 12-channel and (B) the 32-channel coil.

		Frontal GM	Puta-men	Corp. callos.
MP-RAGE	12ch/1mm	35± 5	61± 9	65±11
	32ch/1mm	55±16	94±28	100±31
	32ch/.8mm	49±13	80±21	82±22
MP2RAGE	12ch/1mm	27± 4	65± 9	74±12
	32ch/1mm	44± 9	96±18	112±25
	32ch/.8mm	33± 6	72±12	84±16

Table 1. Exemplary SNR values for different acquisition parameters.

Results: Main effects of age are presented in Fig. 1. Reduced t-values were obtained with MP2RAGE, especially in acquisitions with the 12-channel coil. Paired t-tests (Fig. 2) yielded significantly different GM density estimates in widespread cortical and subcortical areas for all comparisons (i.e., different coils, sequences, resolutions). Strongest interaction effects between age and MRI sequence (Fig. 3) were obtained with the 12-channel coil, which diminished for the 32-channel coil. More subtle interactions were obtained for the other parameters. Mean SNR values (group averages ± standard deviations) obtained with different acquisitions are presented in Table 1.

Discussion: The 32-channel coil yielded sensitivity advantages regardless of the imaging sequence. With the 12-channel coil, MP-RAGE detected more wide-spread age-related changes, especially in cortical structures. Most differences between both sequences became insignificant with the 32-channel coil indicating that MP2RAGE benefited more from the improved SNR (and improved parallel-imaging reconstruction) offered by combining more coil elements. A benefit from a higher spatial resolution was not obtained for a scan time below 10 min. Under such conditions, the intrinsic SNR seemed more important than a potentially better segmentation achieved with higher resolution. In view of substantial effects obtained with paired t-tests for all parameters, careful standardization of the acquisition protocol is advocated.

Conclusion: VBM results can be modulated by differences in SNR/CNR obtained with different imaging sequences, especially in acquisitions with the 12-channel coil. MP2RAGE seemed less prone to false positive results from combining data acquired with different hardware. While the current investigation focused on aging effects, similar results are expected for other VBM studies using the same processing pipeline, for example on plasticity or neurodegenerative diseases.

References:

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