Diffusion tensor invariants and principal eigenvector coherence changes with field strength at various *b*-value ranges

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Introduction A previous study revealed that fitting of the diffusion tensor model at high *b*-values is detrimental to the precision of the principal eigenvector calculated in white matter (WM) and reduces fractional anisotropy (FA) [1]. In our experiment, we aim to determine the effect of magnetic field strength on tensor parameters at *b*-values ranging from 0 to 3000 s mm^{-2}. To date, previous studies on the effect of field strength on tensor invariants have been contradictory and, as far as we are aware, no comparisons have been made at high *b*. Overall, we found significant increase in FA with field strength, at all *b*-value intervals, in WM and thalamus regions of interest (ROI). FA also showed a decreasing trend with increasing *b* in WM. Field strength effect on principal eigenvector coherence, κ, was significant for the majority of our ROIs. Coherence increased with field strength in WM - with implications for tractography where reduced principal eigenvector spread is advantageous in regions of highly organised WM.

Method Eight healthy adults (three women, five men; median age, 26; range 23-27) were scanned on 1.5 T Avanto and 3.0 T Trio Siemens MRI systems with a double refocused pulsed diffusion-weighted (DW) EPI sequence. Maximum gradient strength = 40mT m^{-1} was used in twenty diffusion sensitised directions. Voxel resolution = 2.5 x 2.5 x 5mm. Four acquisitions were made over 25 slices, at b = 0, 1000, 2000 and 3000 s mm^{-2}. Other sequence parameters were TR/TE/NEX = 4100ms/112ms/2. 1000 Wild bootstraps [2] were created of *b*0, *b*1000, *b*2000 and *b*3000 data, using the last DW acquisition. Bootstrap samples were fitted with the diffusion tensor between intervals *b*0-1000, *b*0-2000, *b*0-3000, *b*1000-2000 and *b*2000-3000. The coherence of bootstrapped principal eigenvectors was calculated at each voxel for all tensors [3, 4]. FA and mean diffusivity (MD) maps were generated from the average of all four DW acquisitions. ROIs were drawn in the genu and splenium of the corpus callosum, the centrum semiovale (CS), thalamus and the putamen on FA maps. A two-way repeated measures ANOVA test was performed with main factors field strength and *b*-value intervals. Within-subject effects, Greenhouse-Geisser corrected results are reported. Paired *t*-tests were carried out between field strengths at each *b*-value interval for all invariants.

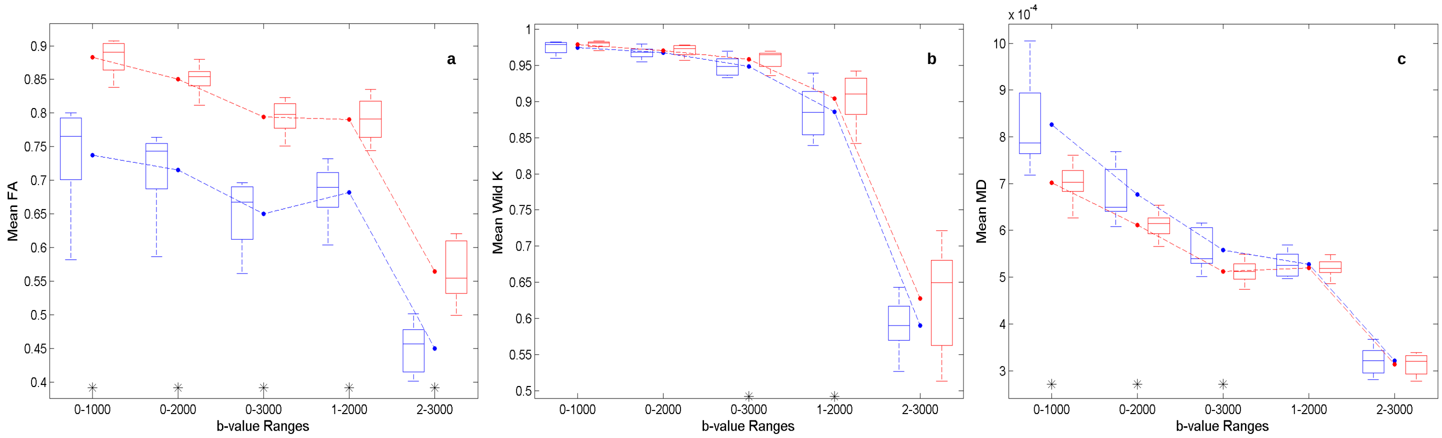

Figure 1 - Mean FA (a), κ (b) and MD (c) box plots from tensors fitted at *b*-value ranges 0-1000, 0-2000, 0-3000, 1000-2000, 2000-3000 for the splenium. Dashed lines graph the mean tensor invariant with *b*. 1.5 T data is in blue, 3.0 T in red for all subjects. * denotes significance of invariant with field strength from paired *t*-tests (P < 0.05).

Results Figure 1 shows box plots of the mean FA (a), κ (b) and MD (c), for all subjects, against *b*-value intervals (*b*0-1000, *b*0-2000, *b*0-3000, *b*1000-2000, *b*2000-3000) for the splenium of the corpus callosum. Dashed lines plot subject group means of tensor invariant at each *b*-value interval. 1.5 and 3.0 T data are in blue and red respectively. Significant paired *t*-test results for invariants between field strength are denoted by '*' at relevant *b*-value interval. All WM ROIs exhibited FA decreasing as *b* increased (as in Fig. 1a), for both field strengths. For all ROIs, κ (Fig 1b) and MD (Fig 1c) decreased with increasing *b*. Table 1 shows significance results from the univariate analysis. Both field strength and *b*-value were significant effects on FA κ and MD when interaction effect was insignificant (except thalamus κ). The interaction effect is not significant for all κ measurements and in FA when WM is highly organised (such as the splenium of the corpus callosum).

	FA			Coherence κ			MD		
	FS	*b*	Int.	FS	*b*	Int.	FS	*b*	Int.
GENU	Y*	Y*	N	Y	Y*	N	Y	Y*	Y*
SPLENIUM	Y*	Y*	N	Y	Y*	N	Y	Y*	Y
CS	Y*	Y*	Y	Y	Y*	N	N	Y*	Y*
THALAMUS	Y*	Y	Y*	N	Y*	N	N	Y*	Y
PUTAMEN	N	Y*	Y	Y	Y*	N	Y	Y*	N

Table 1 – Results of significance from two-way repeated measures ANOVA for all ROI and FA, κ and MD. Significance (P < 0.05) is marked 'Y' for main effects field strength (FS) and *b*-value (*b*). and interaction (Int.). * denotes highly significant.

Discussion Coherence was greater at 3.0 T than at 1.5 T in WM ROIs, most likely due to an improvement in SNR providing better estimation of the principal eigenvector by the tensor model. This is accompanied by a significant increase in FA at 3.0 T for all WM over all *b* intervals tested (paired *t*-test results). Other previous field strength studies have found overall significant increase in FA and decrease in MD with field strength for WM [5, 6] as well as no significant changes for either invariants [7] (all with data acquired at b <= 1000 s mm^{-2}). The observed decrease in FA in WM coupled by a reduction in coherence with increasing *b* is consistent with previous findings [1]. The increase in GM FA with *b* found in [1] was observed in the putamen and the thalamus (although only for 3.0 T data in the latter case). In summary, our results indicate a significant effect from field strength on FA and the coherence of the principal eigenvector in WM.

References [1] Chung AW et al., 15th ISMRM 2006, #1511, [2] Davison AC and Hinkley DV, 1997, Bootstrap methods and their application, Cambridge Press, [3] Basser PJ and Pajevic S, MRM 2000; 44:41-50, [4] Jones DK, MRM 2003; 49:7-12, [5] Huisman TAGM, et al., Eur Radiol 2006; 16:1651-1658, [6] Fushimi Y, et al., NMR Biomed 2007; 20:743-748, [7] Hunsche S, et al., Radiology 2001; 221:550-556. Sponsored by Research into Ageing, grant #256.