# Effects of Diffusion Weighting Scheme and SNR on DTI-derived Fractional Anisotropy at 1.5T

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**Introduction:**

Diffusion tensor imaging (DTI) has an unusually high number of data acquisition parameters and a low signal to noise ratio (SNR). There is great interest in optimizing DTI acquisitions to improve the accuracy and precision of DTI-derived contrasts, and assessing the compatibility of results from multi-center studies. However, as there is no standard DTI protocol, the quantity and composition of DTI data can differ within or between imaging sites due to practical time constraints or the use of different diffusion weighting (DW) schemes. Given that gains in the SNR of DTI-derived contrasts are commonly made by 1) DTI scan repetition or 2) increasing the directional resolution (number of unique diffusion weighted images acquired in each DTI dataset), the aim of this study was to investigate the practical impact of these acquisition parameters on fractional anisotropy (FA) measures in a clinically feasible DTI study. Previous work [1, 5] has shown that SNR significantly affects measures of diffusion anisotropy, and simulation studies [2, 3] have shown how noise and the optimality of the diffusion weighting scheme impact measures derived from DTI. We confirm these results, and assess the intra session and test-retest variation of FA by selecting optimal subsets of DW directions from a scan session. This approach is efficient and differs from previous methods in that it eliminates the need to perform separate DTI acquisitions with different diffusion weighting schemes.

**Data Acquisition and Analysis Methods**

A 24 year old male was studied in three scanning sessions of 15 DTI scans over two days at 1.5T (Intera, Philips Medical Systems, The Netherlands) after written informed consent. A multi slice, spin echo, single-shot EPI sequence (SENSE factor = 2.0) was used to acquire 25 slices parallel to the AC-PC line (no slice gap), 2.5 mm isotropic resolution. Diffusion weighting was applied along 30 directions [2] (b = 1000 s/mm$^2$, G = 19.5 mT/m) and five minimally weighted images (b0) (b ≈ 33 s/mm$^2$) were acquired (TR/TE = 2956/100 ms). All data sets were co-registered with FLIRT [4]. The time to acquire 30 DWIs and 5 b0 images was 2:18 min (one scan time unit, STU). To provide FA maps as a function of directional resolution, optimal subsets of 6 (CN 1.82), 10 (CN 1.62) and 15 (CN 1.65) directions were selected from the full set of 30 (CN 1.59) using a potential energy minimization method (CN = condition number). To ensure an equal scan time comparison of the subsets, DTI data from a session were grouped without replacement, with a $N_{DWI}$:$N_{b0}$ ratio of 6:1. For FA as a function of scan repetition (N STUs) using an optimal set of size M, we combined 30*N/M observations from scans in a session. For example, for one STU 30 DWIs were constructed from 5, 3, 2, and 1 scans of the 6, 10, 15 and 30 DWIs, respectively. Each DWI was an entry in the unconstrained log-linear diffusion tensor calculation. Four regions of interest (ROIs) were manually delineated in the splenium of the corpus callosum (scc), internal capsule (ic), globus pallidus (gp) and putamen (put) to include 237, 151, 180 and 143 pixels respectively.

**Results, Discussion and Conclusion:**

For clarity, we define FA(M,N) as the FA map calculated from a set of DWIs that utilize M diffusion weighting directions, spanning N STUs. A reproducible upward bias was found in the low anisotropy regions (putamen and globus pallidus), especially with less than 2 STU **Fig. 1**. The standard deviation of FA within the ROIs was ~ 0.05 (not shown). The increased noise and bias of FA(30,1) relative to FA(30,15) can be appreciated in the FA maps and the mean difference of the 15 observations of FA(30,1) and FA(30,15), **Fig. 2**. The bias in the low FA regions (putamen and globus pallidus) relative to FA(30,15) within the same scan session were significant in an unpaired t-test ($p \leq 0.05$) up to 5 STUs (not shown). The mean intra-session coefficient of variation (CV) and mean test-retest variation for the 30 direction scheme decreased with scan repetition in all four ROIs (**Fig. 3** & **Fig. 4**). The directional resolution of the DTI data whether as 30 unique DWIs, or sets of the optimal 6, 10 or 15 DWIs did not impact mean FA in the equal scan time comparison (**Fig. 5**). The mean FA and within ROI standard deviation are shown for the internal capsule and putamen at one STU in **Fig. 6**. In summary, by grouping DW data from a scan session, we show that 1) scan repetition alleviates the bias in FA observed at low SNR and 2) in an equal scan time comparison FA measures were not sensitive to diffusion weighting schemes with similar condition numbers. In order to quantify low FA regions, for example, more than 3 STU are recommended while the impact of directional resolution is not a dominant factor at 1.5T with the above mentioned TE.

**References:** [1] Skare et al. JMR (2000) 147:340; [2] Jones D.K & Basser P.J. MRM 52:979-993 (2004); [3] Jones D.K. MRM 51: 807-815 (2004); [4] Jenkinson et al. NeuroImage (2002) 17:825, [5] Pierpaoli C, Basser PJ, MRM, 36(6):893-906 (1996)

**Fig 1: Mean FA in ROI over all sessions for 30 direction scheme**

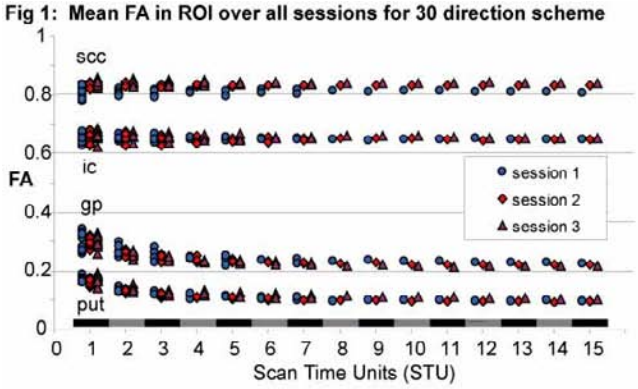


**Fig 2: MPRAGE FA(30,1) FA(30,15) Mean Delta**

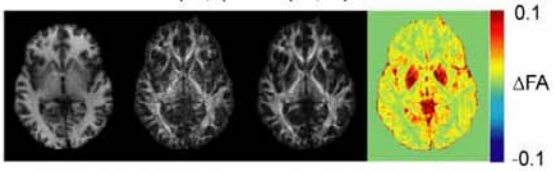


**Fig 3: Intra session variation**

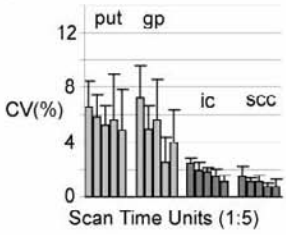


**Fig 4: Test-retest variation**

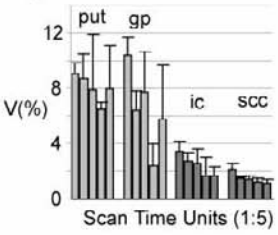


**Fig 5: Mean FA in ROI for session 1 for all direction schemes**

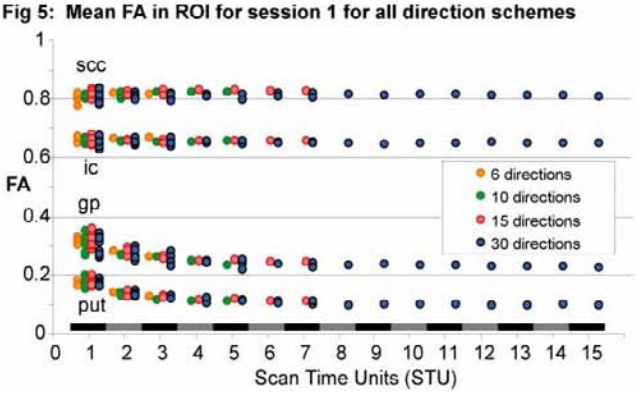


**Fig 6: Mean FA and stdev in ROI at 1 STU**