Weighted Combination of Multichannel ^{1}H-MRS Data: Comparison of SNR- and SVD-based Methods by simulated, *in vitro* and *in vivo* data

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Purpose

The use of phased array RF coils in MRS examinations can substantially improve the achievable SNR of MR spectra. However, suitable weighted linear combination (WLC) of the single channel data is essential for an optimal quality of spectra [1]. Commonly, channel weights can be adjusted according to the signal-noise-ratios of several channels (WLC_{SNR} [2]). However, for decreasing signal-noise-ratios (SNR) the weighting factors become increasingly erroneous, producing an unpredictable amplification of noise dominated channels which can dramatically reduce the SNR of the combined data. A more robust weighting method is based on Singular Value Decomposition (WLC_{SVD}) of data matrix $\boldsymbol{X}$ of the channel signals as described by *Sandgren et al.* [3]. In this study we quantitatively compare both methods using simulated as well as experimental *in vitro* and *in vivo* data.

Material and Methods

Simulated 12 channel data (BW: 2 kHz; N_{fid}: 8192) were generated sixteen times ($N_{set,sim}$ = 16) for two different SNR sets: SNR_{low} = 10 and SNR_{high} = 50. The simulated signal consisted of two 8 Hz damped complex sinusoids with a chemical shift of 2.01 and 4.7 ppm and with an amplitude ratio of 2:1. *In vitro* and *in vivo* single voxel ^{1}H-MR spectroscopic data sets were acquired on a 3 T whole-body MR scanner (Magnetom TIM Trio, Siemens, Erlangen, Germany) with a 12-channel head matrix coil using a PRESS sequence (TR_{vitro}/TR_{vivo}/TE = 10000/2000/30 ms, BW = 4 kHz, $N_{samp,fid}$ = 4096, manual shim) with (NEX = 256) and without (NEX = 16) water saturation. A dynamic series of 14 *in vitro* spectra ($N_{set, vitro}$ = 14) was measured from a 1 ml cubic voxel, placed in the center of a 500 ml sphere containing an aqueous NAA-solution (20 mM). A dynamic series of five *in vivo* spectra ($N_{set, vivo}$ = 5) were extracted from a 1 ml voxel located in the anterior cingulate cortex (ACC) of a 30-year-old healthy male volunteer. Prior to combination the single channel data sets were phase and eddy current corrected using the corresponding water signal [4]. Simulated as well as experimental multi-channel data were combined by the simple linear combination (*SLC*) as well as by using the WLC_{SNR}-, and WLC_{SVD}-approaches. SNR was defined as the ratio of NAA peak at 2.01 ppm and the root-mean-square of signal free spectrum interval between 0 and -1 ppm. The number of finally averaged acquisitions (NAS) was adjusted for all *in vitro* and *in vivo* sets to obtain two target SNR values of SNR_{low} = 10 (NAS_{vitro} = 1, NAS_{vivo} = 20) and SNR_{high} = 50 (NAS_{vitro} = 40, NAS_{vivo} = 256). Variation coefficients (100×sd/mean) of weights calculated by WLC_{SNR} and WLC_{SVD} were used to evaluate the accuracy of weights determination of simulated and acquired datasets. The gain of the NAA amplitude at 2.01 ppm in WLC_{SNR}- and WLC_{SVD}-generated spectra relative to SLC was calculated representative for the overall signal gain.

Results

Coefficients of the channel weight variance extracted for WLC_{SNR} and WLC_{SVD} for simulated and experimental data were up to 6 times smaller at SNR_{high} = 50 than at SNR_{low} = 10. However, compared to the WLC_{SVD} approach, channel weights calculated with WLC_{SNR} revealed a more substantial variance for both adjusted SNR levels (Fig. 1). As summarized in Table 1 and demonstrated with SNR_{high} *in vivo* spectra in Fig. 2 WLC_{SVD}-based weight determination provided a higher signal gain (up to 12%) in all data sets except for SNR_{low} *in vivo* data.

Conclusions

Correct determination of channel weights is essential for the quality of the combined spectra since the SNR improvement provides better quantification accuracy, especially for spectra strongly dominated by J-coupling effects [5]. As demonstrated by means of the higher signal gain and the low variance of the weighting factors among successively acquired spectra, the WLC_{SVD}-based approach was superior for the extraction of true signals from multi-channel spectroscopic data sets, especially at low SNR. Furthermore, the up to twelve times lower variance of weighting factors calculated by the WLC_{SVD} at SNR_{low} indicates higher robustness of this approach compared to WLC_{SNR}. The relative inferiority of WLC_{SVD}, however, in the SNR_{low} *in vivo* data may be the result of a limited number of acquired datasets ($N_{set, vivo}$ = 5). This should be investigated in future studies by successively increasing the N_{set}.

References

[1] Natt, O. *Magn Reson Med 2005*; 53:3-8. [2] Brown, MA. *Magn Reson Med 2004*; 52:1207-1213. [3] Sandgren, N *et al. J Magn Reson 2005; 179:79-91.* [4] Klose, U *Magn Reson Med 1990; 14:26-30.* [5] Bartha R. *NMR Biomed 2007*; 20:512–521.

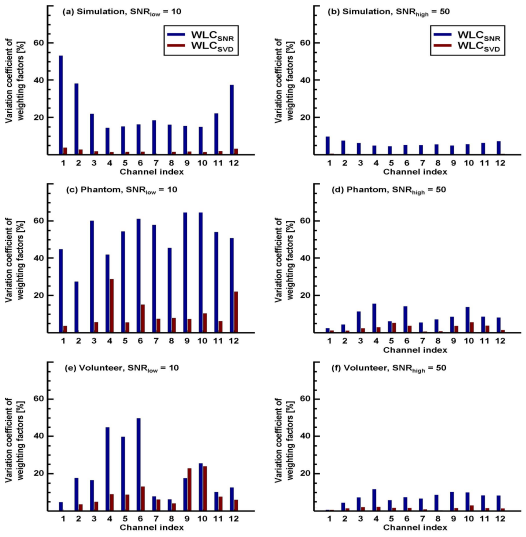

Fig. 1: *Variance coefficients of channel weights extracted with WLC_{SNR} (blue bars) and WLC_{SVD} (red bars) among 16 simulated (a/b), 14 in vitro (c/d) and 5 in vivo (e/f) data sets for SNR_{low}=10 (left column) and SNR_{high}=50 (right column).*

Tab. 1: *Gain of the averaged NAA amplitude of simulated and experimental data combined with WLC_{SNR} and WLC_{SVD} approaches relative to simple non-weighted channel combination (SLC).*

	SNR	Simulation		Phantom		Volunteer	
		WLC_{SNR}	WLC_{SVD}	WLC_{SNR}	WLC_{SVD}	WLC_{SNR}	WLC_{SVD}
Gain [%]	10	4	6	14	26	11	7
	50	5	5.5	22	23	12	17

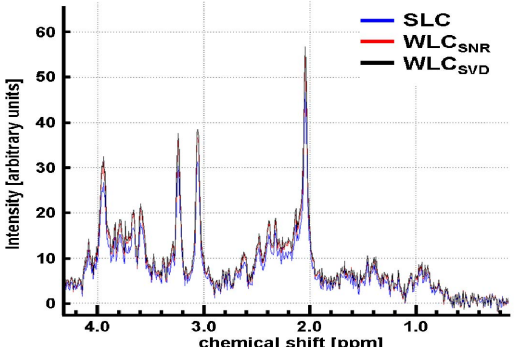

Fig. 2: *In vivo spectra reconstructed from the 12-channel data set (NAS = 256) by using non-weighted channel combination (blue), WLC_{SNR} (red) and WLC_{SVD} (black). As quantified by the amplitude of the NAA peak at 2.01 ppm signal gains of 12% and 17% were achieved using the WLC_{SNR} and WLC_{SVD}, respectively, relative to SLC.*