Acquisition-weighted CSI with a Small Number of Scans

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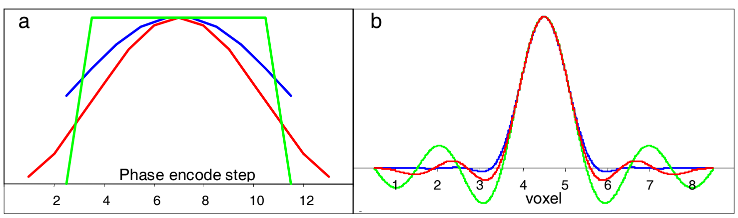
Introduction:
Acquisition-weighting (1,2) has by now become a universally recognized technique to reduce contamination in chemical shift imaging experiments. A good compromise between localization and duration is to use the Hanning-function, which can be defined as (3):

$$w(|k|) = \frac{\beta}{2}\cdot\left(1+\cos\left(\frac{2\pi\cdot|k|\cdot\Delta x}{\alpha}\right)\right)$$

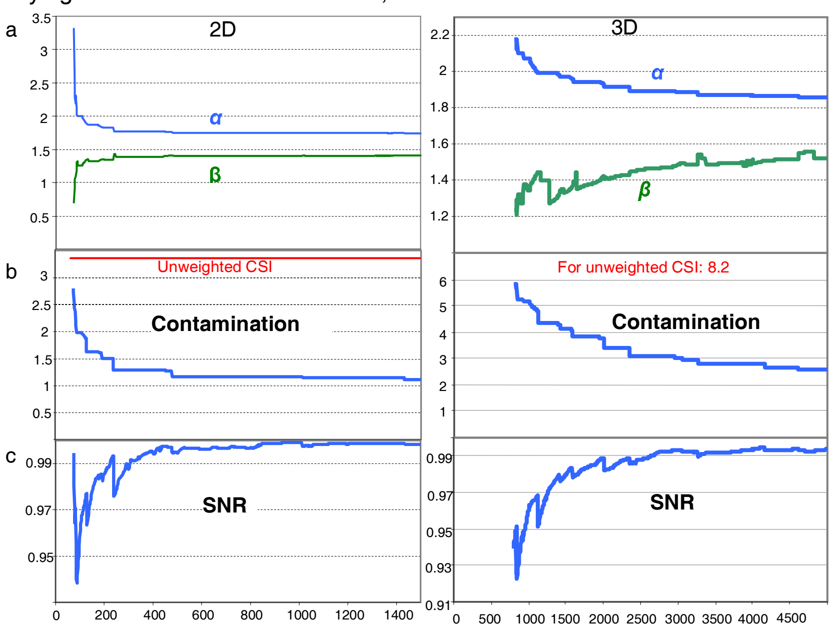
(Δx: voxel size), where the parameter α serves to adjust the width of the weighting function, and thus the spatial resolution, while β determines the total number of scans. For high scan numbers, both parameters depend only on the number of spatial dimensions. While this weighting scheme is commonly used for experiments where a large number of scans is necessary for sensitivity reasons, experiments with only few more scans than voxels are often performed without any weighting, resulting in large contamination and poor spectral quality. The aim of this study was to determine theoretically whether acquisition weighting is beneficial also for those experiments and how a small number of scans influences the experimental parameters as well as contamination and SNR.

Theory:
In a Hanning-weighted CSI experiment, the number of averages depends on the position in k-space. Deviations from the theoretical Hanning function are corrected afterwards by additional numerical weighting of the phase encode steps. Reducing the scan number cuts off the outer parts of the weighting function due to rounding, which causes a convolution of the point-spread function with a sinc. This affects the spatial resolution by increasing the width of the PSF. One way to avoid this is by adjusting the parameters α and β to keep the width of the PSF constant. As a drawback, this causes an increase in contamination and may also – since it increases the post-measurement corrections – affect the SNR.



Weighting schemes (a) and resulting PSFs (b) for an unweighted experiment (green), an optimally weighted experiment (pink) and a measurement with number of scans equal to 1.25 times the number of voxels (blue). By adjusting α, the width of the PSF remains unchanged. In spite of the relatively small number of scans, the contamination is almost completely suppressed. Parameters of this simulation are: 2D-experiment, resolution 8×8, red experiment consists of 80 scans.

The graphs below show for a 2- and 3-dimensional experiment the values for α and β needed to obtain a constant width of the PSF with varying number of scans. In addition, values for the contamination and the SNR are shown and compared to unweighted CSI.



a: The parameters α and β needed in a 2D (left) and a 3D (right) CSI experiment to reach a resolution of 8×8 (2D) and 8×8×8 (3D) voxels, as function of the total number of scans.
b: The higher α value needed in short experiments to reach the desired resolution causes a cutoff of the weighting function and thus a higher contamination. Even for short experiments, where the number of scans is only slightly larger than the number of voxels, the contamination is clearly smaller than for unweighted CSI (red line).
c: The SNR of the weighted experiment is slightly reduced due to the need for additional weighting after acquisition to correct for the integer number of averages. For unweighted CSI, SNR=1. For an unweighted experiment which is weighted after measurement, SNR = 0.82.

Conclusion:
Even for a relatively small number of scans of only slightly more than the number of voxels, acquisition weighting can strongly reduce the contamination and improve the quality of the measurement. However, to keep the desired resolution, the weighting function has to be adjusted by correctly setting the parameters α and β.

References:
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