

Is the BOLD sensitivity reduced at a short TR in fMRI? A theoretical study.

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Introduction

- A shorter T_R (repetition time) is desired for better timing information of the BOLD response in particular in the study of cognitive event timing.
- However, it is well known that the attainable MRI signal level will be reduced due to the saturation of the MR signal at a shorter T_R , which could lead to the reduced BOLD sensitivity.
- But, I still want to have a short T_R . How much of the BOLD sensitivity am I losing then?

Methods & Results

Optimum rf angle

- The rf angle (Ernst angle) to maximize the MRI signal of the gray matter for a given T_R (1):

$$\theta_{opt} = \cos^{-1} \left[\exp \left(-\frac{T_R}{T_1} \right) \right]$$

- T_1 : longitudinal relaxation time
- T_1 of the gray matter at 3 T = 1209 ms (2)

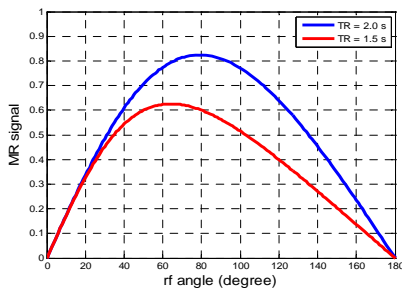


Figure 1. Variation of MR signal by the rf angle for T_R of 1 and 2 sec.

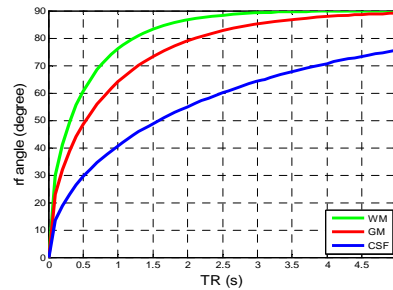


Figure 2. Optimum rf angles at different T_R for different brain tissues. T_1 of white matter and CSF are 699 and 3600 ms, respectively.

MR signal at the optimum rf angle

$$M(T_R) = \frac{\sin \theta_{opt}}{1 + \cos \theta_{opt}}$$

Sampling gain in fMRI

- A shorter T_R will provide more temporal sampling within the given task duration.
- In reference to $T_R = 3$ sec, the relative sampling gain is

$$G_{samp}(T_R) = \sqrt{3/T_R}$$

The total signal at T_R in reference to $T_R = 3$ sec

- The total GM is the product of the GM signal and the sampling gain.

$$M(T_R) = \sqrt{\frac{3}{T_R}} \left(\frac{\sin \theta_{opt}}{1 + \cos \theta_{opt}} \right)$$

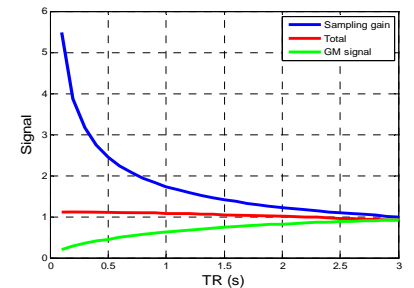


Figure 3. The total signal.

Conclusions

- The total signal remains relatively flat for the range of T_R , which suggests that the short TR will not compromise the BOLD signal considering that the BOLD signal is from the GM.
- The reduced CSF signal at a shorter T_R could contribute to the reduction of the physiology noise and the partial volume effect in the voxel containing both GM and CSF.

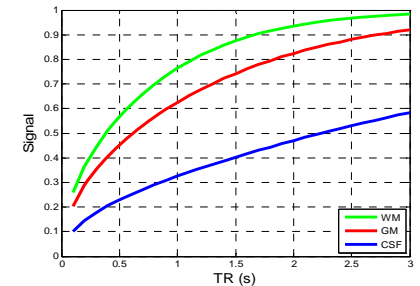


Figure 4. Saturation of tissue signals at the optimum rf angle for GM.

References

- EM Haacke, et al., Magnetic Resonance Imaging Physical Principles and Sequence Design, Wiley-Liss.
- Hanzhang Lu, et al., JMRI 2005 (22), pp 13 -22.

Acknowledgments

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