# Study of the linearity in BOLD response in spinal fMRI

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**Purpose.**

FMRI approaches have been sparsely attempted for the study of the spinal cord function; however, obtaining good functional images of the spinal cord still represents a technical and scientific challenge. Spinal cord fMRI may be of immediate application in neuroradiology, in particular for the assessment and follow-up of spinal injuries, pain, and neurodegenerative diseases (e.g. multiple sclerosis), as well as in the development and evaluation of new therapies. Nonetheless, the exact features of functional response, and even the biophysical origin of the signal, are still unclear. Task dependent modulation of spinal cord fMRI activations in response to thermal, sensory, motor and painful stimuli, have been reported thus far (1-2), and an hemodinamic response function (hrf) specific for spinal cord has been proposed (3). In the present work, we performed a controlled motor task (graded isometric force) of the right dominant hand, and we parametrically studied the relationship between stimulation strength and functional response.

**Methods.**

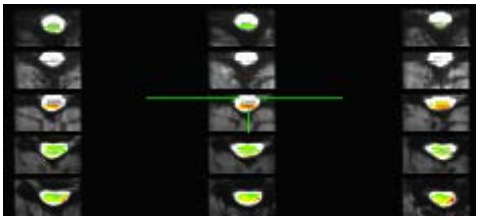

**Fig.1:** Activation map of a representative subject. P<0.001 Right side is on the left.

Functional MRI data were acquired using a neurovascular coil array, on a 3T scanner (Philips Medical Systems, Best, The Netherlands). 10 healthy subjects participated in this study and performed a block-designed motor task. Subject were asked to press a force-sensitive device between their first and second finger, until a visual feedback confirmed that the target force was reached. Each run included alternating 30-s rest and motor task epochs, during which target forces of either 10%, 20% or 50% of the subject's own maximal sustained force (MSF) were required in a pseudorandom order. The actual developed force was digitized and recorded. For each subject, 3 gradient-echo EPI runs were acquired, with the following parameters: TE=25 ms, flip angle 75°, TR=2500ms, 20 parasagittal slices, 1.5 mm thick. fMRI data underwent optimized processing (RETROICOR physiological noise reduction, masking, motion correction, slice timing, smoothing). Subject specific activations were obtained by GLM fitting of the regressors computed by convolution of the prescribed force with the spinal cord hrf. Percent amplitude of the functional response was then extracted from the thresholded maps (p<0.001), and compared with the normalized exerted force, after binning and time-shifting corresponding to the interval from onset to maximum of the hrf. Custom Matlab routines incorporating spm8 and afni functions were used.

**Results and discussion.**

We found a congruent task-related fMRI response. Positive signal changes were mostly detected at C4–C7 vertebral levels, with a tendency to lateralize to the ipsilateral side of the spinal cord (figure 1).
We found a significant linear dependence of functional response on the task intensity (i.e. exerted force, Figure 2, p<0.05 on the slope). Note that the force values are the result of a binning operation on the recorded force, that span almost continuous values between 0 and about 55% of MSF across subjects, because of the subjects inability to keep a steady force. Inequality of variance is partially due to varying population of the bins.
This result suggest a strong parametric dependence of functional response in the spinal cord on the stimulation strength in an isometric motor task. Such a dependence is important, because confirms the physiological origin of the response, and is of great help in model-based fMRI inference.

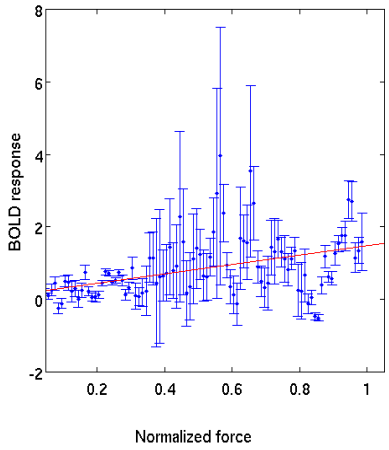


**Fig.2:** plot of the BOLD response as a function of the measured force, with the relevant linear fitting. Data are mean±SEM of percent BOLD increase within responding areas. Force is normalized to 1 (corresponding to the last bin, ≥50% of MSF.)

**References**

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