Spatial extent of task-induced fMRI-BOLD response after hemodynamic scaling using resting state fluctuations

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Introduction: This study evaluated hemodynamic scaling of fMRI-BOLD response to a fingertapping task using vascular reactivity information contained in the resting state fMRI signal. This novel scaling parameter (i.e) resting state physiological fluctuation amplitude (RSFA) was compared with established scaling factors such as BOLD response amplitude to breath hold (BH) or 5%CO_2.

Methods: Eight healthy volunteers (3 females; 5 males) aged between 23-67 years with no history of head trauma, neurological disease or hearing disability were scanned. All images were obtained on a 3T-MR scanner. In each volunteer, echo-planar images were obtained across the motor cortex in the axial plane (64x64 matrix, TR/TE=1 sec/27.2 msec, FOV=20 cm, 6 slices, slice thickness=7 mm and bandwidth 125kHz). The imaging procedure for each volunteer was as follows: sagittal localizer images were first obtained with a conventional gradient echo sequence. The mid sagittal image was used to select six axial slices covering the motor cortex for functional imaging. Images were obtained under different conditions namely (a) rest while breathing room air, (b) bilateral fingertapping (c) breath holding (BH) and (d) breathing a mixture of air+5%CO_2. For the finger-tapping task, subjects were instructed to successively touch each finger with the thumb in a self-paced manner.

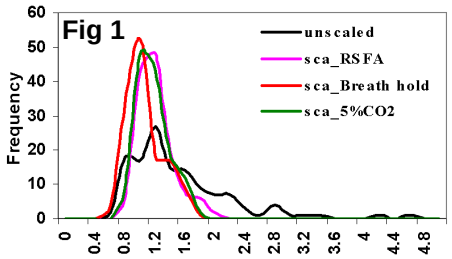
Models established by Davis et al., 1998 and Hoge et al., 1999, define the BOLD signal with the underlying physiological variables CBF and $CMRO_2$. Assuming CBF change is proportional to $CMRO_2$ change and that no change in $CMRO_2$ takes place during the BH task, 5%CO_2 breathing task or during resting conditions when no task is presented, a measurable indicator of cerebral metabolic activity was quantified by dividing the BOLD signal response during the task condition with the BOLD signal response during rest, BH or 5%CO_2 defined as the scaled BOLD response.

Table1: Correlation between RSFA vs breath hold, RSFA vs 5%CO_2 and Breath hold vs 5%CO_2 over all subjects (four subjects breathed 5%CO_2).

subject	correlation (R^2) RSFA vs Breath hold	correlation (R^2) RSFA vs 5%CO_2	correlation (R^2) Breath hold vs 5%CO_2
1	0.78	0.78	0.87
2	0.89	0.92	0.96
3	0.88	0.89	0.92
4	0.74	0.69	0.88
5	0.81	--	--
6	0.88	--	--
7	0.87	--	--
8	0.79	--	--
Group ave	**0.83 ± 0.06**	**0.82±0.11**	**0.91±0.04**

Results: Highest correlation was also observed between BH and 5%CO_2 from corresponding regions in the whole brain and over all subjects (Table 1). A high correlation was observed between BH or 5%CO_2 with RSFA and was reproducible over all subjects (Table 1).

Hemodynamic scaling using RSFA, BH or 5%CO_2 significantly reduced the group average of the BOLD signal change in response to finger tapping by 60% and the group SD by 85%. The overall extent of amplitude scaling obtained using RSFA was comparable to that obtained using either BH or 5%CO_2 (Fig 1).



In a separate analysis, spatial overlap of a fixed population of voxels was compared over different experimental conditions. Spatial extent of the un-scaled with scaled activation on a subject wise basis was performed using 65 highly responding pixels. Scaling with either BH or 5%CO_2 reduced the activation volume with the exception of RSFA in all subjects (Table 2). This indicates a significant alteration in the spatial locations of the highly responding voxels during task-induced fMRI-BOLD activation after hemodynamic scaling when compared to the un-scaled condition. Most importantly, scaling with RSFA avoided the reduction in activation volume after hemodynamic scaling as opposed to BH or 5%CO_2 as they were a relatively strong hypercapnic stimulus leading to scaling out of voxels that may have contained true activation due to neural metabolism.

Table 2: Spatial extent of activation (activation volume in cm^3) in response to the finger-tapping task over all subjects before and after hemodynamic scaling with various parameters.

subject	before scaling	scaling with RSFA	scaling with breath hold	scaling with 5%CO_2
1	20.8	4.0	2.5	3.0
2	7.2	3.5	1.8	2.6
3	76.2	49.3	3.1	18.1
4	17.9	11.5	1.5	3.7
5	55.4	87.3	29.3	--
6	17.2	22.5	1.7	--
7	2.9	21.8	5.2	--
8	31.3	47.9	5.3	--
Group ave	28.6±25.1	30.9±29.4	6.3±9.4*	6.9±7.5**

*significantly different with respect to RSFA, p<0.009, paired t-test
*significantly different with respect to RSFA, p<0.02, t-test unequal variance

Conclusions: All scaling parameters significantly reduced variation in amplitude spatially within subjects and across subjects. RSFA correlated very well with the BOLD signal variation induced by the BH task or breathing 5%CO_2, which indicates that information contained within the resting state BOLD signal in the form of fluctuations depends on the systemic CO_2 change due to spontaneous breathing. In addition to not diminishing the spatial extent of activation, RSFA as a hemodynamic scaling factor would eliminate additional hypercapnic task which is difficult for special populations such as patients, children and elderly and avoid evoked neural activity confounds associated with BH or breathing CO_2.

References

Davis, T., Kwong, K., Weisskoff, R., Rosen, B.R. 1998.. Proc Natl Acad Sci. USA 95, 1834-1839.
Hoge, R.D., Atkinson, J., Gill, B., Crelier, G.R., Marrett, S., Pike, G.B., 1999. Magn Reson Med. 42, 849-863.