First application of whole brain CBV weighted fMRI to a cognitive stimulation paradigm: Robust activation detection in a Stroop task experiment using 3D GRASE VASO

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Introduction

The VASO technique developed by Lu et al. [1] was received with great interest as it permitted for the first time the non-invasive measurement of cerebral blood volume (CBV) changes during brain activation. This has led to a large number of human studies devoted to mechanistic investigations into the brain's hemodynamics. Furthermore, in the light of increasing evidence that blood volume changes occur primarily in the capillaries and/or arterioles, VASO in principle offers the opportunity to detect activation with a spatial specificity much higher than that of BOLD fMRI. The original VASO was proposed as a single slice technique with a GE-EPI readout, which has precluded its application to fMRI studies beyond simple visual and primary motor stimulation. VASO has meanwhile seen many modifications, including the extension to multi-slice coverage by the MAGIC scheme [2,3], or as more recently demonstrated for whole-brain coverage, the use a single-shot 3D GRASE readout [4].

To ascertain the suitability of 3D GRASE VASO for 'real cognitive' fMRI, and within reasonable measurement times, we performed a typical fMRI experiment on 12 subjects as a 'case study', using a colour-word Stroop task [5] as cognitive challenge that evokes well-described activation in many brain areas. Conventional BOLD EPI scans were made for reference; however the aim here is neither the direct comparison nor to demonstrate the superiority of either method.

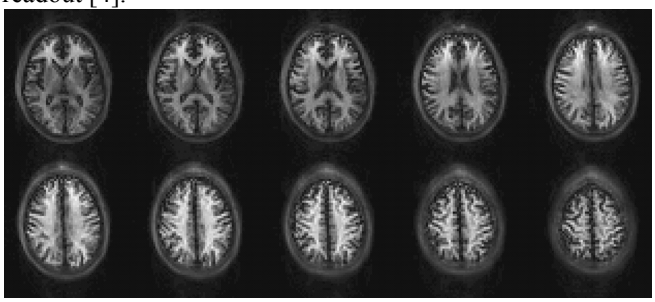

Fig.1 *Sample VASO images*

Methods

Twelve subjects were scanned at 3 T (Siemens), using 3D GRASE VASO with a 32-channel head coil [4]. Whole-brain fMRI was performed at FoV=224x224x100mm^3, matrix 64x64x(20+4 oversampling), GRAPPA factor 4 x 2 along k_y and k_z using product reconstruction, TR/TE/TI=2500/13.9/760ms; scantime was 12.5min, 292 volumes. For reference, BOLD scans with identical geometry were made using multiecho-EPI (TE=25,35,45ms, weighted echo summation [6]), TR=1500ms; scantime was 6.5min, 249 volumes. The cognitive fMRI task was a blocked Stroop colour word matching task as described in ref. [5]; responses were recorded to monitor attention. Standard data processing of all data (MoCo, 8mm smoothing) and 1st and 2nd level analyses were performed in SPM8.

	FFX model (N=12) p<0.00001		RFX model (N=12) p<0.005	
	VASO	BOLD	VASO	BOLD
brain region	max t	max t	max t	max t
L intrapariet. sulcus	9.51	39.16	5.33	8.63
R intrapariet. sulcus	10.84	27.73	7.78	11.31
L post. inf. front. sulcus	13.53	34.24	8.08	9.68
R post. inf. front. sulcus	9.85	25.82	3.38	3.63
L ant. inf. front. sulcus	6.53	18.73	---	4.54
R ant. inf. front. sulcus	5.91	15.38	---	4.61
L occipital cortex	19.29	61.18	11.38	12.51
R occipital cortex	21.22	48.93	11.31	7.85
L lat. occipit. temp. gyrus	17.34	41.48	6.77	12.59
R lat. occipit. temp. gyrus	10.17	45.76	3.79	5.46
SMA	12.73	-38	5.3	10.49
L ventr. front. cortex	-8.33	-10.1	-5.7	-5.48
R ventr. front. cortex	-7.23	-8.65	-13.1	---
L inf. front. pole	-7.41	-9.14	-4.2	-3.33
R inf. front. pole	-8.41	---	-6.71	---
L lat. occipit. pariet.	-8.98	-27.1	-7.81	-8.71
R lat. occipit. pariet.	---	-17.7	---	-6.71
post. cing. cortex	-8.01	-17.3	-7.84	-8.48
R lat. sup. parital	-6.64	-10.4	-6.66	-6.34

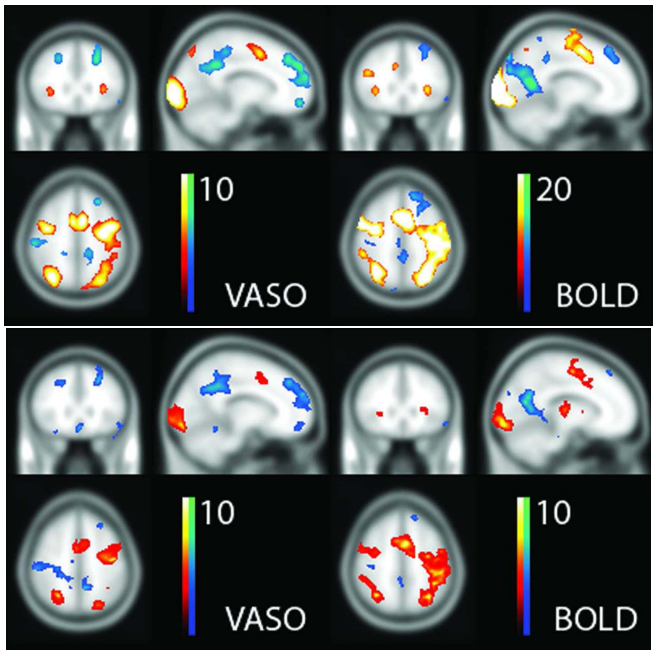

Fig.2 *VASO GRASE reliably detects activation in the whole brain as evident from the t-score maps (N=12) for fixed effects analysis at p<0.00001 (top) and random effects analysis at p<0.005 (bottom).*

Results and Discussion

The GRASE VASO data show the typically reported Stroop activation clusters in both fixed and random effects analyses, as confirmed by comparison with BOLD (see table). Interestingly, VASO performed relatively better in the RFX (2nd level) analysis; a reason for this may be a smaller inter-subject variability in signal changes than in BOLD, which often differs considerably between subjects.

While BOLD is clearly a more sensitive method than VASO, our results show that whole-brain CBV weighted cognitive fMRI studies can easily be realized with 3D GRASE VASO, within very acceptable measurement times (only 12min in this study).

References

[1] Lu H, et al. MRM 2003;50(2):263-274; [2] Lu H, et al. MRM2004;51(1):9-15; [3] Scouten A, Constable RT. MRM 2007;58(2):306-315;[4] Poser BA & Norris DG. MRM 2009;62(1):255-62; [5] Zysset S, et al. Neuroimage 2001;13(1):29-36 [6] Poser BA & Norris DG. MRM 2006;55(6):1227-35