An fMRI and MEG Investigation of Repetition Suppression in the Visual Cortex

R. Vidyasagar[1], A. Stancak[2], and L. M. Parkes[1]

[1]MARIARC, University of Liverpool, Liverpool, Merseyside, United Kingdom, [2]School of Psychology, University of Liverpool, United Kingdom

Introduction

Repetition suppression is a phenomena that has been observed in both human and animal models[1,2]. It has been shown that when a paired stimulus with matching characteristics are presented, there is a reduction in the neuronal response when compared to the response to a pair of stimuli of varied characteristics. To date, there has yet to be a conclusive argument for this reduction of response, primarily due to the variability of paradigm designs leading to different results. Currently, there exist three distinct models to describe the behaviour of neurons that lead to repetition suppression; the fatigue model (less overall activity), sharpening model (fewer neurons respond) and facilitation model (less processing time)[3]. There have been many studies incorporating BOLD fMRI and EEG using simple and complex stimuli that work on the lower and higher level processing capabilities of the visual cortex that try to fit these models, however there has yet to be a study that simultaneously tests behavioural, neuronal and vascular responses to the same paradigm. As the nature of repetition suppression is strongly determined by paradigm design, it is our aim to use a multimodal approach to study responses to the same paradigm.

Methods

9 healthy subjects took part, (5 F, 4 M, mean age 28 years ± 3.9). There was a behavioural, MEG and fMRI component to this study using the same paradigm. Subjects took part in all components. The paradigm consisted of stimulating the visual cortex by the presentation of paired gabor patches in the right visual hemifield. Each gabor patch was presented for 100 msec and had a varying interstimulus interval (ISI) of either 200 or 600 ms. There was a 2 second inter trial interval (ITI) between each pair (increased to 4s for fMRI). The first gabor patch had either a vertical or a horizontal orientation and the second gabor patch was vertical, resulting in 4 conditions in total. A slight tilt either clockwise or anti-clockwise was introduced to the second patch and subjects were required to state the direction of tilt. MR data was acquired on a Siemens 3T Trio system. T2* BOLD data were acquired with a TR: 2.5sec; TE: 35ms; 3mm isotropic voxels. There were 60 trials of each condition. In addition to the paradigm, an extra 2 runs were performed to obtain a retinotopic map, and a localiser scan to map the gabor patch on the visual cortex. MEG data were acquired on a 148 channel 4D – Neuroimaging system. Data was acquired continuously at a sampling rate of 674Hz.

Data Analysis

All BOLD data were motion corrected, temporally filtered and spatially smoothed using a 6mm Gaussian kernel in Brainvoyager (Brain Innovation, The Netherlands). Structural scans were converted to Talairach space and localisers were superimposed onto retinotopic maps to identify three regions of interest, in V1, V2/V3 and MT (V5). Within these regions the Beta weights (i.e. the BOLD amplitude) was found for each of the 4 pair pulsed conditions. MEG data was analysed using BESA (MEGIS software, Germany). All data was cleaned of ECG and EOG artefacts and bandpass filtered (1.5 – 40 Hz) to remove further artefacts. Data were epoched and averaged according to conditions. A generic algorithm involving five equivalent current dipoles was used to construct the grand average source model. The source waveforms from the dipole located in the left occipital cortex were used in the final analysis.

Results

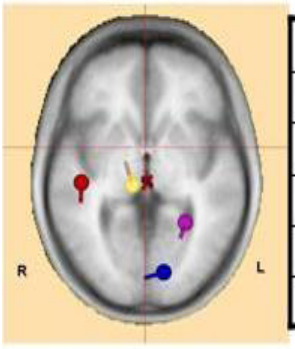

Fig 1. Single subject locations of MEG source dipoles. Blue source represents the occipital dipole.

	First flash (nAm)		Sec Flash(nAm)	
	n100	p200	n100	p200
Hori600	-6.8	10.4	-7.8	13.1
Vert600	-8.9	11.1	-6.9	11.3
Hori200	-8.4	10.3	-7.3	10.5
Vert200	-9.4	10.6	-7.3	*8.3

Table1: MEG amplitudes from key characteristic peaks (n100 at 100msec and p200 at 200 msec following onset of stimulus) of averaged responses from individual conditions. * denotes a significant reduction in amplitude (p=0.05).

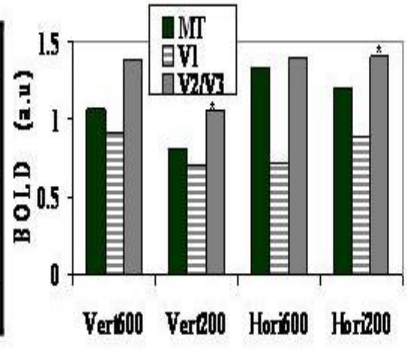

Fig 2. Averaged BOLD responses in different visual areas across various conditions. * denotes a significant reduction in BOLD response($p<0.05$) between the Vert 200 and Hori 200 condition.

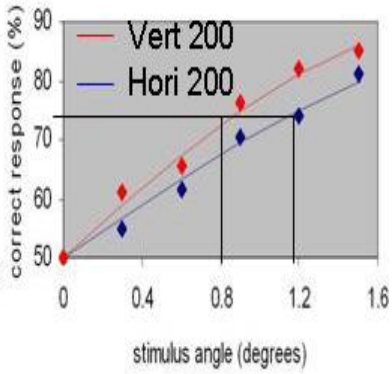

Fig 3. Behavioural data. There is a significant effect at the Vert 200msec condition. Subjects' ability to discern between the stimulus angles was impaired.

Discussion

This study successfully merged data from behavioural, neuromagnetic evoked fields and blood oxygenation changes to show that the repetition suppression in the visual cortex is a neuronal phenomenon. The data shows that across all three modalities there is a significant effect observed when paired vertical gabors were presented at an ISI of 200msec, which are not present at the 600 msec ISI. Whilst an overall reduction was seen in all visual areas at Vert 200msec, only data from the higher visual areas (V2/V3) were seen as significantly affected. This is supported by the significant reduction in the P200 response (but not the earlier n100 response) from the MEG data at the same condition, suggesting suppression of higher level responses. The MEG data showed no change in timing of the second vert 200 response; evidence against the facilitation model. The behavioural data shows impairment of orientation detection for vert 200; evidence against the sharpening model, which would improve performance. The data appear to be best explained by the fatigue model[3], which suggests that repetition suppression effects are possibly due to a reduction in the number of neurons that fire. The lack of significant effects in the V1 area has also been observed in a previous study using a similar paradigm design[4]. The higher level effects might also be attributed to the demands set by the task.

References:1. Ogawa et al, PNAS, vol 97, 20, 2000. 2. Henson et al, Neuroimage, 21, 2004. 3. Grill-Spector et al, Trends in Cognitive Sciences, Vol 10, 1, 2006. 4. Murray et al,JNeurophys, 95, 2006.