fMRI OF CONTRAST RESPONSE IN VISUAL CORTEX

Frans W. Cornelissen[+], Denis G. Pelli, Bart Farell, Nick Szeverenyi*

Institute for Sensory Research, Syracuse University, NY, USA and *Department of Radiology, SUNY HSC, Syracuse, NY, USA
[+]Present address: Laboratory for Experimental Ophthalmology, University of Groningen, The Netherlands

Introduction

This study examined the effect of visual noise on the MR response of the brain to visual signals. Observers viewed gratings or words at various contrasts while they were being scanned. This allowed us to establish a contrast response curve for the MR response in visual cortex. We also determined the observer's psychophysical contrast thresholds for the same words and gratings.

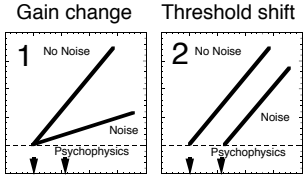
Noise

The key to our technique is the use of visual noise. Psychophysically we find that signal-to-noise ratio is a powerful univariant: For any particular signal and task, threshold corresponds to a fixed signal-to-noise ratio, independent of contrast.

The signal contrast in both figures is the same. Adding visual noise to the background makes it harder to see the signal. Psychophysically, noise shifts threshold to higher contrast.

Hypotheses

What could happen to the MR response in the presence of visual noise?

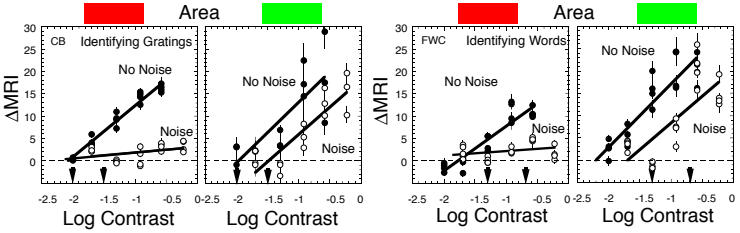


We take threshold to be the zero intercept of the line, and gain to be its slope.

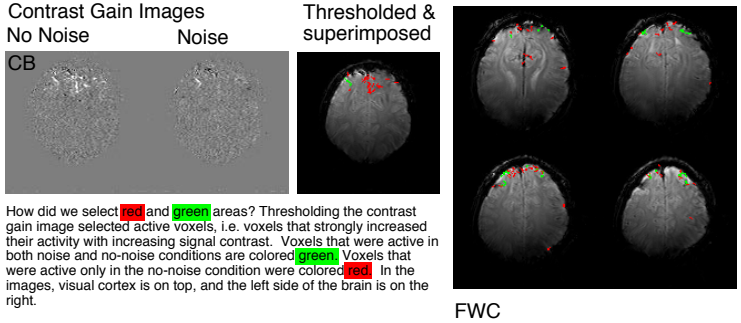
1. Gain change.
There is substantial physiological evidence for a non-selective contrast gain control in area V1, so the gain of the response to the signal might be reduced in the presence of a visual noise background.

2. Threshold shift.
The response of some cortical area may parallel the psychophysics, where all that matters is signal-to-noise ratio. This predicts that the response function would shift half a log unit to the right, to higher contrasts. The down-pointing arrows, on the bottom of the graph, show the psychophysical thresholds with and without noise. Noise raises threshold by a factor of about 3 (~0.5 log).

Results



Two areas (red and green) respond to the signal. Each response corresponds to one of our two hypotheses. Near threshold, the contrast response is initially zero and then rises linearly as a function of log contrast. In red areas (presumably cortical visual area V1), masking the target by visual noise greatly reduces gain with no effect on threshold. In green areas (mainly cortical areas outside V1), the threshold is shifted half a log unit (like the psychophysical threshold), and gain is unchanged.



How did we select red and green areas? Thresholding the contrast gain image selected active voxels, i.e. voxels that strongly increased their activity with increasing signal contrast. Voxels that were active in both noise and no-noise conditions are colored green. Voxels that were active only in the no-noise condition were colored red. In the images, visual cortex is on top, and the left side of the brain is on the right.

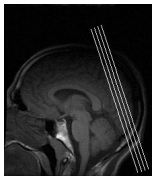
Discussion

Our red and green brain areas exhibit qualitatively different effects of visual noise. What are these brain areas doing?

For the red area, our data support the popular idea that contrast is normalized in area V1. The fact that the threshold is unaffected indicates a linear response, without the kind of noise-dependent thresholding one would expect for decisions about the presence of features.

In the green area, we find that the physiological MR response to the signal is affected in exactly the same way as the psychophysical performance of the observer. In both cases the response or performance depends solely on the signal-to-noise ratio, independent of contrast. This indicates that the MR response of the green area results from a computation that is quite similar to the computation that underlies the observer's psychophysical performance.

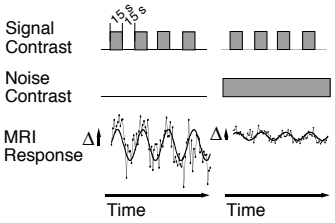
Method



We used a 1.5 Tesla GE scanner equipped with an echo planar image acquisition system. Images were collected using a T2* weighted echo planar sequence with a TE of 60 ms and a TR of 1500 ms. Four slices were aligned parallel with the calcarine sulcus of the subject, as is shown in the figure.

Slice thickness was 6 mm with an in-plane pixel size of 1.6 x 1.6 mm. During a run we collected 80 images for each slice with 1.5 sec in between images. A run therefore lasted 120 secs. During a scanning session we performed approximately 10-12 runs. Different signal contrasts were assigned in random order to the runs.

Stimulus Presentation



fMRI Data Analysis