Negative Dip Imaging in Bold Functional MRI

Larry Shepp, Cun-Hui Zhang,

Rutgers U.

Martin Lindquist,

Columbia University

Gary Glover,

Stanford University

Higher cognition involves mental processes of hundreds of milliseconds, for example, we can recognize George Bush in such a brief time, even from the back, or from the side.

Since Descartes, people have wondered how such recognition is possible. Many gedanken experiemnts and conjectures have been made.

Functional magnetic resonance imaging allows one to hope that

measurements will be able to answer these questions. fMRI measures the difference in the density of oxyhemoglobin and deoxyhemoglobin.

Understanding cognition demands that the measurement times be comparably short, i.e. within hundereds of milliseconds.

Until now, most fMRI labs have relied on “refresh blood” which

arrives to resupply a pool of oxygenated blood about one to three seconds after the oxygen has been depleted.

Let me draw the "hemodynamic response function" believed by many to be at least qualititively descriptive of the way oxygen is resupplied locally to tissues.

One argues that there is an evolutionary advantage to having a pool of oxygenated blood in those

areas of the brain where rapid functioning is required. These areas can be found by viewing refresh blood, but to understand what is happening when there is more than one area in the brain involved in carrying out a given task - say recognizing a predator - as there seem to be several steps in the task (what is the intruder? - my mother?, George, a lion?) presumably carried out in different regions, it is important to be able to know which

of several areas in the brain was involved earlier and which later. That is how to order the events temporally.

Refresh blood arrives seconds later, and so presumably sometimes in permuted order, depending on the refresh blood supply, i.e. the arterial tree. These are small arteries so we are not going to know the tree.

Thus real time negative dip imaging is needed.

We believe we can show that this is feasible even at 3 Tesla. The new fMRI machines are now coming along at 7 Tesla and the results should be evn better. I will show some real data indicating that refresh blood can permute the order, and that negative dip may be used to get the true order.

We use keyhole sampling based on a 3 dimensional space-filling

trajectory developed with Gary Glover.

We apply a filter, ϕ, whose Fourier transform vanishes on the set where we have *not* sampled k-space. ϕ is chosen to maximize the square integral over a resolution element.

ϕ trades off spatial resolution for temporal resolution.

We show definitively that in the usual experiment with a flashed

image and a button press that there is first a negative dip in the visual cortex when the image is flashed, and then a negative dip in the motor cortex about 200 msec later.

The important result is that we can also observe "third regions" where negative dips appear in the *intervening time period*.

We believe these regions are involved in processing the various

steps or aspects of the visual and the motor tasks.

We regard these results as a strong indication that bold imaging can be used to do real-time fMRI.