

orm for  
entations  
Y OF  
RESONANCE  
D MEETING  
O HILTON & TOWERS  
ISCO, CA, USA  
ust 6-12, 1994

entation but  
nt as a poster  
at willing to make  
on

ned (available only  
entations)

ORIES  
OULD FILL IN A  
ATEGORY

Y   
d Studies  
ar Studies  
mo—Techniques,  
lek  
mo—Clinical  
pic and Other  
r  
mes  
a—Human Studies  
ay

al  
e and Marrow  
tal Sports Medicine  
ing  
MRI  
am Imaging

PY   
Imaging Techniques  
spectroscopy  
Quantitation  
System—Human  
System—Animal  
System—Methods  
Methods and Animal  
Clinical  
Fiber  
Other

on  
al, including bone  
tissue and Animal  
al  
ing body fluids

GY   
ation

od Solid Imaging  
Coils and Hardware

ation Imaging  
es Techniques  
imaging  
sing  
culating  
hamus MFC  
Contrast Agents  
Agents  
mence and FSR  
es

EDLINE:  
than April 12, 1994.  
accepted abstracts become the  
HE. No proprietary information  
s authors.

ley Office  
nitive Meeting  
osty Avenue, Suite 3C  
CA 94704 USA

abstracts from outside the  
w six weeks for mailing or  
w express.

nt clearly the name and complete  
the first author

Jesmanowicz  
Research Institute  
al College of Wis.  
ertown Plank Rd.  
WI 53226

(4) 266-4000  
(4) 266-4007

## Frequency Shift Artifacts in Functional Echo - Planar Imaging

A. Jesmanowicz, P. A. Bandettini, and J. S. Hyde

Biophysics Research Institute, Medical College of Wisconsin, Milwaukee, WI

### PURPOSE:

It is well established that activation-induced hemodynamic changes cause localized changes in MRI signal (1-3). Negatively correlated signal changes and very large signal changes are commonly observed. One explanation for the negative correlation involves a "steal" phenomena: (e.g. increase in blood oxygenation in active pixels causing a corresponding decrease in adjacent pixels). Large signal changes may be interpreted as foci of neuronal activation. This study is based on the desire to interpret these suspicious signal changes.

These abnormal signal changes were observed where image signal intensity showed a steep gradient, such as at the edge of the brain or near sharp gray/white matter borders. We hypothesize that abnormal time course signal changes arise from susceptibility-induced frequency shifts (probably in voxels having large vessels), which cause subvoxel shifts; therefore causing some spatial shifting of a region of high (or low) signal intensity into a region having low (or high) signal intensity. These large effects are not observed in regions where MR signal contrast is low. At the resolutions commonly used in our echo-planar imaging (EPI) experiments, a change of 20 Hz causes a shift of one voxel in the phase encode direction.

To support our hypothesis, we determined that  $B_0$  shifts (TE independent) and large signal intensity gradients at TE > 80 ms spatially corresponded with the correlation coefficient sign change that occurred at TE > 80 ms.

### METHODS:

Imaging was performed on a 1.5 T GE Signa scanner. Single shot blipped gradient-echo EPI was performed using a three-axis balanced torque head gradient coil and an endcapped quadrature whole brain birdcage transmit/receive rf coils. Resolution =  $3.75 \times 3.75 \times 5 \text{ mm}^3$ . TR = 1 sec. Time-course series of one axial plane through the motor cortex, consisting of 200 images each, were performed using TE values of 30, 40, 60, 80, 100, and 110 ms. During each time course, cyclic (20 sec on, 20 sec off) bilateral finger tapping was performed.

At TE above 80 ms, some pixels showed a negative correlation to activation timing; in contrast to a positive correlation at shorter echo times. A time course of  $B_0$  field maps were created by a) complex conjugate multiplication of real and imaginary components of images at TE values of 30 and 100 ms. and b) calculation of the arctan of the product (4). Time course series of both magnitude images and  $B_0$  field maps were analyzed and compared.

### RESULTS:

Figure 1 displays  $4 \times 4$  time course plots from the same region in motor cortex. At TE = 30 ms (Fig. 1a), all pixels demonstrated positive temporal correlation with the finger tapping task. At TE = 100 ms (Fig. 1b) and 110 ms, the response in voxel 1 showed a negative temporal correlation. The argument that the change is due to a "steal" effect is inconsistent with the data obtained at shorter echo times that only show positive correlations.

Figure 1c shows a large and correlated change in  $B_0$  in voxel 1. The peak to peak  $B_0$  change was approximately  $(2\pi/\gamma) \times 4 \text{ Hz}$ , causing a sub-voxel shift in the phase encoding direction. In the presence of a homogenous signal near this voxel, dramatic changes would not be expected. When large signal gradients exist between voxels, sub-voxel shifts cause signal changes (+ or -) depending upon signal gradient direction relative to the shifts.

In this case, short TE values produced small steady state contrast between voxels 1 and 3 (the phase encode direction). At TE longer than 80, contrast between voxels 1 and 3 increased such that a sub-voxel shift caused a large negatively correlated signal change which dominated over the intrinsic activation-induced response. This shift is evident in voxel 3, which does not have a response at TE = 30 ms, but shows a positively correlated signal change at TE = 100 ms, possibly shifted signal from voxel 1. Signal intensity gradients caused by contrast between bone and brain signal may explain changes of up to 60% which are occasionally observed.

### CONCLUSIONS:

A new mechanism for extremely large or negatively correlated signal changes is characterized. These results can mimic intense positive or negative activation in areas that are non-activated or weakly activated.

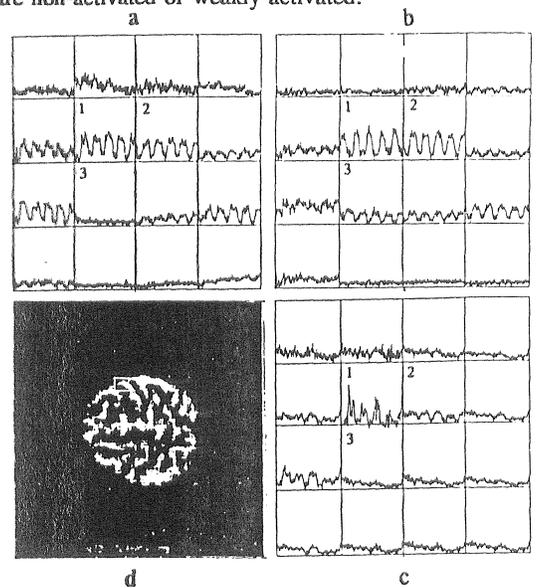


Figure 1:  $4 \times 4$  time courses: a) magnitude at TE = 30 ms, b) magnitude at TE = 100 ms, and c)  $B_0$  map time course. d) Image showing the selected  $4 \times 4$  region in motor cortex.

### REFERENCES:

1. Kwong KK, et al. Proc. Natl. Acad. Sci., USA 89, 5672, (1992).
2. Ogawa S, et al., Proc. Natl. Acad. Sci., USA 89, 5951, (1992).
3. Bandettini PA, et al. Magn. Reson. Med 25, 650 (1993).
4. Weisskoff et al. 11th SMRM Ann. Mtg. 4515 (1992).