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Analysis of Phase Differences in Periodic Functional MRI Activation Data

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INTRODUCTION:

Rapid echo-planar MR imaging of local cerebral oxygenation changes could potentially enhance understanding of the temporal characteristics of task performance in distributed neural networks. A difficulty with this approach is that event-related MR signal responses occur over several seconds [1], reflecting the time course of vasodilatory phenomena, whereas neuronal events are likely to occur on a much more rapid time scale. We describe a method for improving delineation of sequentially activated brain areas using analysis of phase shift differences in regularly oscillating functional MRI activation data.

METHODS:

Five healthy, right-handed subjects were scanned in a sagittal plane using a GE Signa 1.5 T magnet, a 30.5 cm. i.d. three-axis local gradient coil, and an endcapped quadrature birdcage whole-brain rf coil. A blipped gradient-echo EPI sequence was used (TE = 40 msec, TR = 3 sec, FOV 24 cm). Image resolution was 64 x 64, with a slice thickness of 10 mm. Auditory stimuli consisting of digitized human speech were used for brain activation [2]. Subjects were instructed to listen to the stimuli, but no other task was required. Stimuli were presented at precisely controlled intervals using a computer playback system. Activation was performed in a periodic manner, with 9 sec stimulus periods alternating with 9 sec baseline periods over 10 complete cycles.

Correlation coefficients, r, were calculated for each pixel by correlating raw signal data with a reference sinusoidal function, f [3]. An automated procedure was used which incrementally phase-shifted f until the best r value was obtained for each pixel. The phase shift, ϕ, of each pixel response was defined as the phase shift of f producing a maximal value of r for that pixel. Active pixels were defined as those attaining a correlation of $r \geq .50$ ($p < .05$, corrected for multiple comparisons).

RESULTS:

Phase shift values of f producing the best r value varied from pixel to pixel by as much as 3 seconds. Figure 1 illustrates the relationship between r and phase shift of the reference function for three pixels in the left temporal lobe of one subject. The three pixels in this example were spaced along the dorsal aspect of the superior temporal gyrus at three posterior to anterior locations, and showed phase shifts of roughly 1 second between each location.

CONCLUSIONS:

Analysis of the phase shift of regularly oscillating activation data may provide a means of identifying small temporal response differences between brain areas active during functional MR imaging. This technique would be particularly applicable to the temporal analysis of behaviors characterized by extended, sequential activity, as in cognitive tasks that involve widely distributed neural networks.

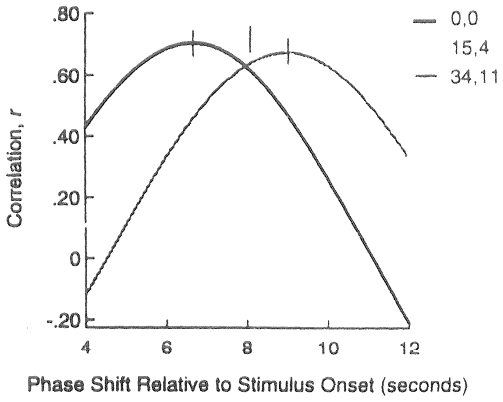

Figure 1: Correlation coefficient, r, as a function of phase shift of the reference sinusoidal function, f, for three pixels in the left superior temporal gyrus. Relative coordinate locations, in mm, of the three pixels are given at top right, with increasing X,Y values indicating more anterior and inferior locations. Small vertical lines indicate ϕ, the phase shift of f resulting in a maximal value of r.

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