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Temporal Characteristics of Functional Magnetic Resonance Signal Change in Lateral Frontal and Auditory Cortex

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INTRODUCTION:

Temporal characteristics of the signal change observed in unimodal sensory and motor cortex during functional magnetic resonance imaging (FMRI) have been described previously [1,2]. Signal rise from baseline to peak values in these studies was typically complete within the first 10 sec of brain activity, while signal decrement to baseline values after cessation of brain activity occurred over similar or slightly longer intervals [1]. We have recently demonstrated FMRI responses in polymodal frontal cortex (Brodmann areas 6, 45, and 46) during a semantic language processing task [3]. The purpose of this study is to compare the temporal characteristics of these frontal responses with responses occurring in unimodal auditory cortex of the superior temporal gyrus (BA 22).

METHODS:

Three healthy, right-handed subjects were scanned in a lateral 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 and voxel dimensions of 3.75 x 3.75 x 10 mm.

Stimuli consisted of digitized pure tones and human speech, presented at precise intervals using a computer playback system. A pure tone discrimination task was used to activate unimodal auditory sensory cortex. In this task, subjects heard groups of 3 to 7 sequential tones of either 500 or 750 Hz frequency. A response, consisting of briefly lifting the left forefinger, was required for any tone sequence containing two occurrences of the 750 Hz tone. A semantic decision task was used to activate lateral frontal cortex. In this task, subjects heard spoken nouns designating animals and were required to respond to those words meeting both of two specified semantic criteria. Target words designated animals that were both "native to the United States" and "used by humans."

Tasks were performed in a periodic manner, with 24 sec of task alternating with either a resting state or another task over 16 full cycles. Tone discrimination alternated with rest during some image series, and semantic decision alternated with tone discrimination during others. Active pixels were identified by correlating data with reference sine functions on a pixel-by-pixel basis [4,5], with a significance threshold, corrected for multiple comparisons, of $r > .45$ ($p < 10^{-6}$). Normalized data from active pixels in the left superior temporal gyrus and in the left lateral frontal lobe were averaged to generate a mean response curve for each region.

RESULTS:

Temporal response characteristics of superior temporal and frontal cortex differed significantly. Figure 1 illustrates mean results of 528 normalized activation cycles obtained from frontal cortex and 96 cycles from superior temporal cortex of one subject (error bars = 95% confidence intervals). Unimodal sensory cortex of the superior temporal gyrus showed the expected rapid rise to peak values in less than 10 sec in all subjects (approximately 6 sec for the subject shown), and relatively rapid fall to baseline after task cessation. In contrast, lateral frontal signal increased more slowly in all subjects, peaking approximately 18-24 sec after task initiation. Signal decrement was also slower in frontal than in superior temporal cortex, reaching baseline levels approximately 15-18 sec after task cessation.

CONCLUSIONS:

The time course of FMRI signal change in polymodal frontal cortex during a cognitive task differs from that seen in sensory cortex during a sensory discrimination task. The explanation for the prolonged rise time in frontal cortex is unknown, but could reflect an attentional mechanism acting to compensate for fatigue or habituation. The findings impact on studies of cognitive activity using FMRI, suggesting the need for activity periods of at least 20 sec for maximal signal change to be observed in polymodal cortex. For analysis methods using cross-correlation techniques, these results emphasize the need for specific descriptions of activity in polymodal cortex in order to generate appropriate reference functions.

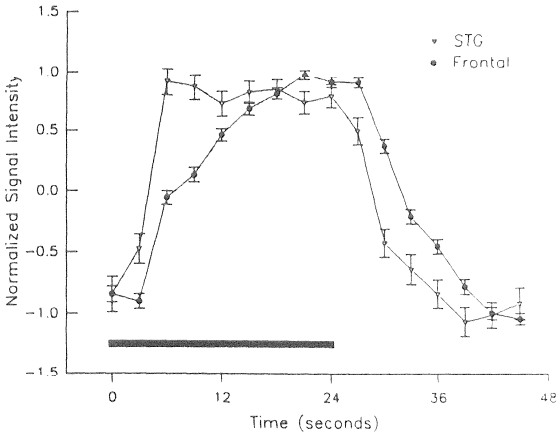

Figure 1. Time course of signal response in superior temporal gyrus (STG) and lateral frontal cortex. Thick horizontal line indicates 24 sec of task performance.

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