MAPLE (Mapping Activation as a Percentage of Local Excitation) fMRI mapping: Stability within scan, between scans, and across field strengths

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BOLD fMRI statistical activation mapping is sensitive to the number of trials collected, scanner signal-to-noise sensitivity, and variability in task performance. Standard mapping methods can produce maps with different numbers of active voxels in each run even under carefully controlled conditions (Liu et al., 2004 MRM 52:751-760). To address this issue we have developed an adaptive fMRI mapping approach, based on an empirical consideration of how statistically defined brain activations evolve over space and time. Our hypothesis is that the statistical significance of BOLD responses will increase with repeated task cycles, but the relative spatial pattern of signal amplitudes within localized clusters should remain fairly stable.

Methods: We tested this MAPLE (Mapping Activation as Percentage of Local Excitation) method by comparing spatial extents of t-value activations using fixed thresholds (9 t-value levels: t >= 2-6 in 0.5 t steps) versus adaptive thresholds (at 10 different percentages, 10%-100%, of the average peak t-value for the ROI) in fMRI scans of 9 healthy volunteers performing simple language (silent speaking) and motor (hand flexion) tasks. For each active ROI, spatial extent was calculated as number of voxels at or above each threshold level. Only voxels with t-values above a minimum threshold (t >= 2.0) were included in the analysis.

Results: In standard fixed threshold mapping, the number of voxels at each threshold and the spatial maps of active voxels changed continuously with increased scan time (Fig1A, Fig 2A). With MAPLE mapping, the number and spatial pattern of voxels at each threshold level wais stable over scan time (Fig 1B, Fig 2B). When a single subject performed the same task using different pulse sequences (EPI or Spiral) or at different field strengths (1.5T or 4T), at the end of each scan the number of voxels at each fixed threshold level was highly variable across runs (Fig3A) but was essentially constant using MAPLE adaptive thresholds (Fig3B). What did change in the MAPLE maps was how many different threshold contours were statistically significant, but not the voxels within each adaptive threshold level.

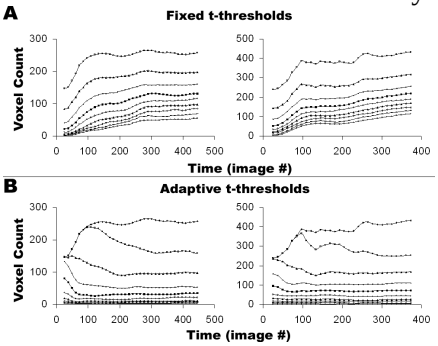


Fig 1. The number of active voxels at each threshold as a function of scan time for a language (left) and a motor (right) task. Counts at fixed thresholds kept rising, but MAPLE counts stabilized

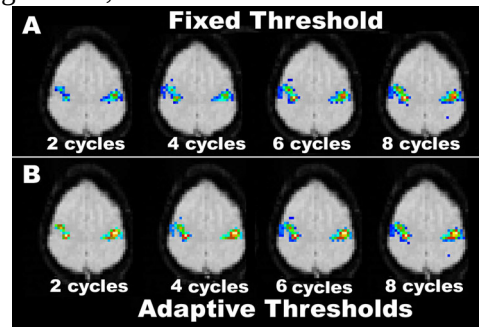


Fig 2. Motor maps as a function of scan time (36s per task cycle). **A)** standard t-value color-color t-maps changed with time, **B)** percent-of-peak color-coded MAPLE maps grew but did not change color over time.

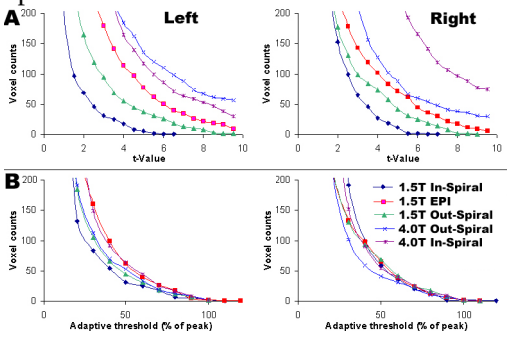
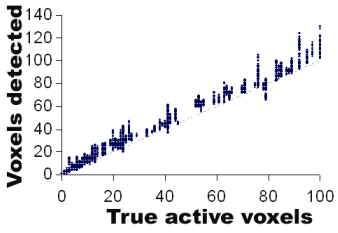


Fig 3. The number of active voxels for each hand as a function of threshold for 5 different runs of a motor task using EPI, Inward Spirals, Outward Spirals at 1.5T or 4T. **A)** standard fixed thresholds, **B)** MAPLE thresholds.

Simulations: We performed MAPLE spatiotemporal analysis on simulated fMRI data sets with known numbers of "active" voxels (the distribution of spatial location and signal amplitudes of simulated active voxels were copied from real language and motor active areas). Counts of active voxels detected using the MAPLE analysis method were very close to the true number of active voxels at every adaptive threshold level (10-100% of peak) in every ROI



Discussion: The stability of the MAPLE method has two important practical implications for fMRI mapping: 1) it provides a quantitative way to assess the quality of an fMRI scan by measuring how stable the spatial pattern of voxel activation is over time for a particular task condition, and 2) it provides a way to meaningfully quantify the intrinsic spatial distribution of fMRI activation patterns.