Isolated Spike-like Transients (ISLTs) in Functional MR Timeseries: Evidence for Vendor and Field Strength Effects on Rates

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Introduction: Most statistical models of fMRI data are very sensitive to extreme outliers. We have noticed isolated, spike-like transients in fMRI timeseries that, from a statistical point of view, constitute outliers. These events are frequently ignored, but can have marked deleterious effects at several stages of fMRI analysis. Using data from 10 scanners, (Phase I Functional BIRN, see below), we have found vendor (Siemens vs GE) and field-strength effects on the rate of occurrence of these events.

The Functional BIRN is a consortium of 12 sites throughout the USA (http://www.nbirn.net/TestBeds/Function/index.htm) that are all doing fMRI studies together. As an initial step, a single group of 5 subjects were studied at 9 sites (10 scanners) using several activation tasks. GE (n=5), Siemens (n=4) and Picker (n =1) scanners were employed. Half of these scanners operated at low field (1.5T, n=5) and half at high field (3.0T, n= 4, 4.0T, n=1). This provided an excellent opportunity to compare the rate of occurrence of ISLTs across vendor and field-strength.

FIGURE 1

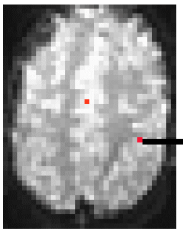
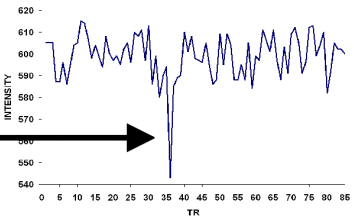


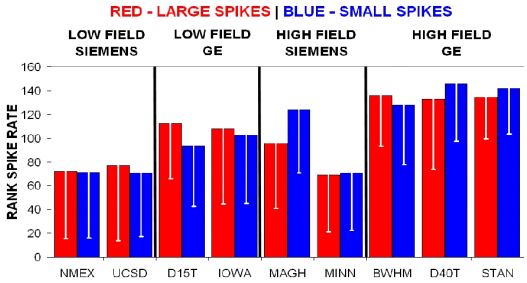
FIGURE 2



Methods: Five healthy normal volunteers traveled to 9 sites (10 scanners). All were male, young (early 20's), right handed, with 20/20 vision (uncorrected). All subjects participated in 2 fMRI sessions, each on a separate day. The present analysis is based on a single activation task, i.e., the "sensorimotor" task, as designed by Dr. Gary Glover. The task employed a block design, and involved bilateral alternating finger tapping at 3Hz to a 3Hz set of tones accompanied by a 3Hz flashing checkerboard. All sites used a bite bar for head restraint.

ISLTs were detected on unprocessed images, using the AFNI program 3dToutcount (http://afni.nimh.nih.gov/afni/AFNI_Help/3dToutcount.html). The time series is detrended with a 2nd order polynomial, using a form of regression less sensitive to outliers (L1 norm regression). The median absolute deviation of the time series minus the trend is computed. Points that are far away from the trend are termed outliers. The degree of deviance of an outlier is defined by its "q" value, which is analogous to a p-value in least squares (L2 norm) regression, and is an index of the probability that an event occurred by chance. We counted ISLTs with 2 thresholds, q = 0.0000000000001 (1.0E-14) and with the default threshold (q = 0.001, 1.0E-3). The ISLT in Figure 1 and Figure 2 has a q=1.0E-12.

FIGURE 3



ISLTs at both thresholds were counted for all 5 subjects at 10 scanners for two sensorimotor task runs for two visits (200 observations total). Each sensorimotor task consisted of 85 TRs, with TR=3.0 sec, or 4.25 min.

Statistical Analysis: The count data were not normally distributed and so all statistics were performed on the ranks of the counts. The rank data were analyzed with non-parametric and parametric approaches (Conover, 1971). The results from both approaches were substantively identical, and so only the parametric approach will be presented here. The data were analyzed in a factorial ANOVA with field-strength, vendor and the field-strength by vendor interaction modeled. The rank data were formally tested for normality of residuals and homogeneity of variance and passed both tests. The data from the single Picker scanner was not included in the vendor test. All events throughout the timeseries were counted, so a single voxel could have multiple events.

Results: Although we have not completed a detailed analysis of the distribution and nature of the ISLTs, these events appear to be more likely in areas of high susceptibility artifact. They also frequently occur near edges or in a bright voxel near a dim voxel. However, ISLTs do occur in the parenchyma away from susceptibility artifact (Figure 1).

TABLE 1	High Threshold	Low Threshold
25th Percentile	10	6,491
Median	59	8,587
75th Percentile	233	11,120

The median frequency of occurrence, as well as the 25th and 75th percentile frequency for both thresholds, are presented in Table 1. With approximately 32,000 voxels per image, and 85 TRs per run, the total number of time points analyzed per run was 2,720,000. The mean ranks of the frequencies of ISLTs are graphed for each scanner in Figure 3, divided by vendor (Siemens vs GE) and field-strength (Low vs High) (error bars are standard errors).

High Threshold ISLTs: Figure 3 suggests both vendor and field effects. The results of the ANOVA test (Table 2) support this. There was no field-strength by vendor interaction. The vendor effect was by far the largest effect (approximately 6 times larger F-value than the field-strength effect).

TABLE 2	df	F	Sig.
FIELD	1, 176	4.4	0.037
VENDOR	1, 176	28.3	<0.00001
FIELD * VENDOR	1, 176	0.7	0.39

Low Threshold ISLTs: It was surprising to find that the correlation between the ranks of high threshold ISLTs and low threshold ISLTs was so high, i.e. 0.83, p <0.001. The pattern of results was quite comparable to the high threshold ISLTs, i.e., no interaction, statistically significant vendor (F=18.7, p <0.001) and field-strength (F=17.2, p < 0.001) effects. In this case the F-values for the vendor and field-strength effects has similar magnitudes.

Discussion: ISLTs are present in fMRI timeseries and need to be taken into account during analysis. Obviously these events can have marked effects during motion correction, detrending, smoothing and statistical evaluation. The AFNI program 3dDespike (http://afni.nimh.nih.gov/afni/AFNI_Help/3dDespike.html) is designed to remove these ISLTs and we routinely employ it as the first step in our analysis. We do not know the cause of these events, but further analysis of their anatomical distribution, and relationship to head movements, may provide important clues. The presence of such strong vendor effects is surprising, but may also provide clues to the nature of these unusual events. The increased rate of occurrence of these events at high field may be related to increased susceptibility artifact, but this can not be concluded for certain at this time. It is interesting to note that scanners which employed spiral acquisitions (D15T, D40T and STAN) did not have fewer events than scanners which employed EPI acquisitions. Obviously, further characterization of these ISLTs will be important to understand their cause.

References: Conover, W.J. (1971): Practical nonparametric statistics. Wiley, NYC.