The implications of baseline correction practices in the analysis of event-related potential (ERP) topographies.

Petr Janata & Stefan Tomic
Center for Mind and Brain, University of California, Davis

Summary

In the analysis of event-related potential (ERP) recordings from the human scalp, voltage topographies corresponding to ERP components at various timepoints following stimulus onset are often used to infer loci of neural generators, either by qualitatively associating the potential distribution with underlying brain structures, or through source localization modeling. Stimulus and task-related processing functions are thus associated with presumptive neural generators.

We surveyed 200 papers published between 2001 and 2003 in **Cognitive Brain Research**, **J. Cognitive Neuroscience**, **Psychophysiology**, **Clinical Neurophysiology**, **Cerebral Cortex**, **Neuroscience Letters**, and **Neuroreport** to assess the prevalence of topographic mapping and baseline correction procedures. Baseline correction has been a prevalent practice since the days of recording from relatively few electrodes. Baseline correction removes the mean value in a window preceding stimulus onset on an electrode-by-electrode basis. Thus, this operation defines the mean scalp topography during the baseline window as having a uniform distribution of zero, effectively "silencing" any sources that are active during the baseline window period. Post-stimulus topographies now represent the difference between the true post-stimulus topography and the baseline window topography. In this poster we illustrate these issues with a simple simulation using known sources and a realistic head model.

To the extent that task relevant generators are consistently active preceding the onset of stimuli of interest, as is often the case in context-probe and delayed match to sample designs, incorrect inferences about ERP components following stimulus onset and their underlying generators may result if ERPs are not interpreted relative to the baseline period.

Data are rarely analyzed at all recording sites

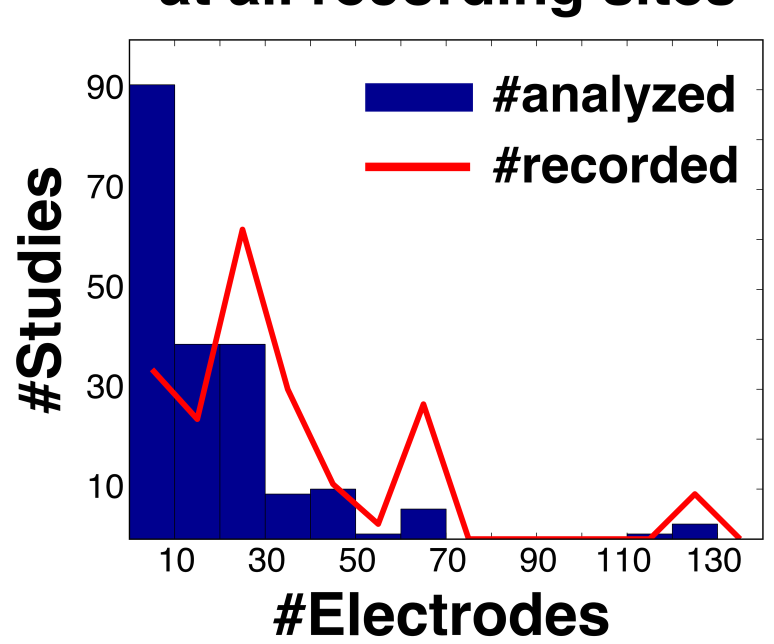

Figure 1. Distribution of the number of electrodes from which data were recorded in each of 200 studies. Topographical maps were shown in 48.5% (97/200) and statistically analyzed in 36% (72/200) of the studies.

Commonly used baselines

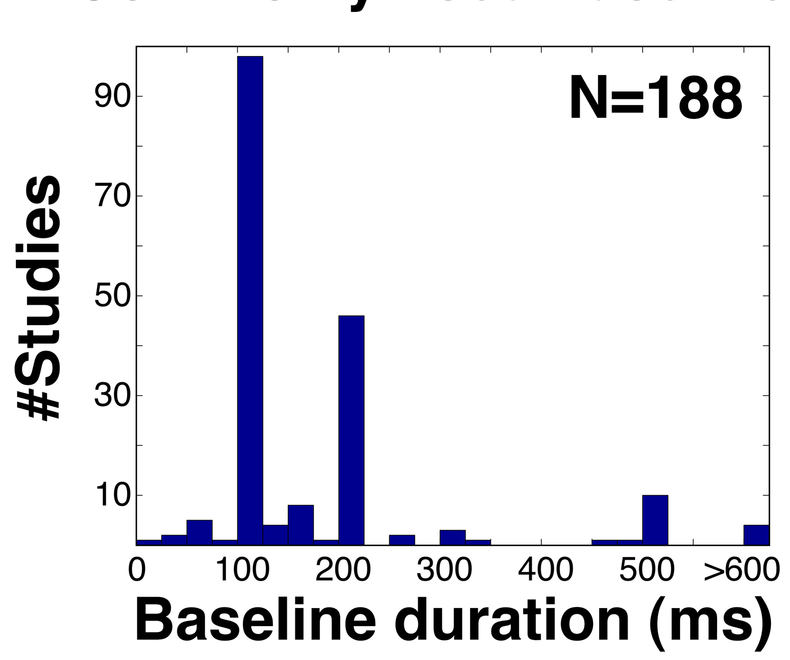

Figure 2. Distribution of the reported amounts of time preceding event onset that were used for baseline correction of ERP waveforms in 188 of the studies analyzed. Data were unavailable for 12 studies.

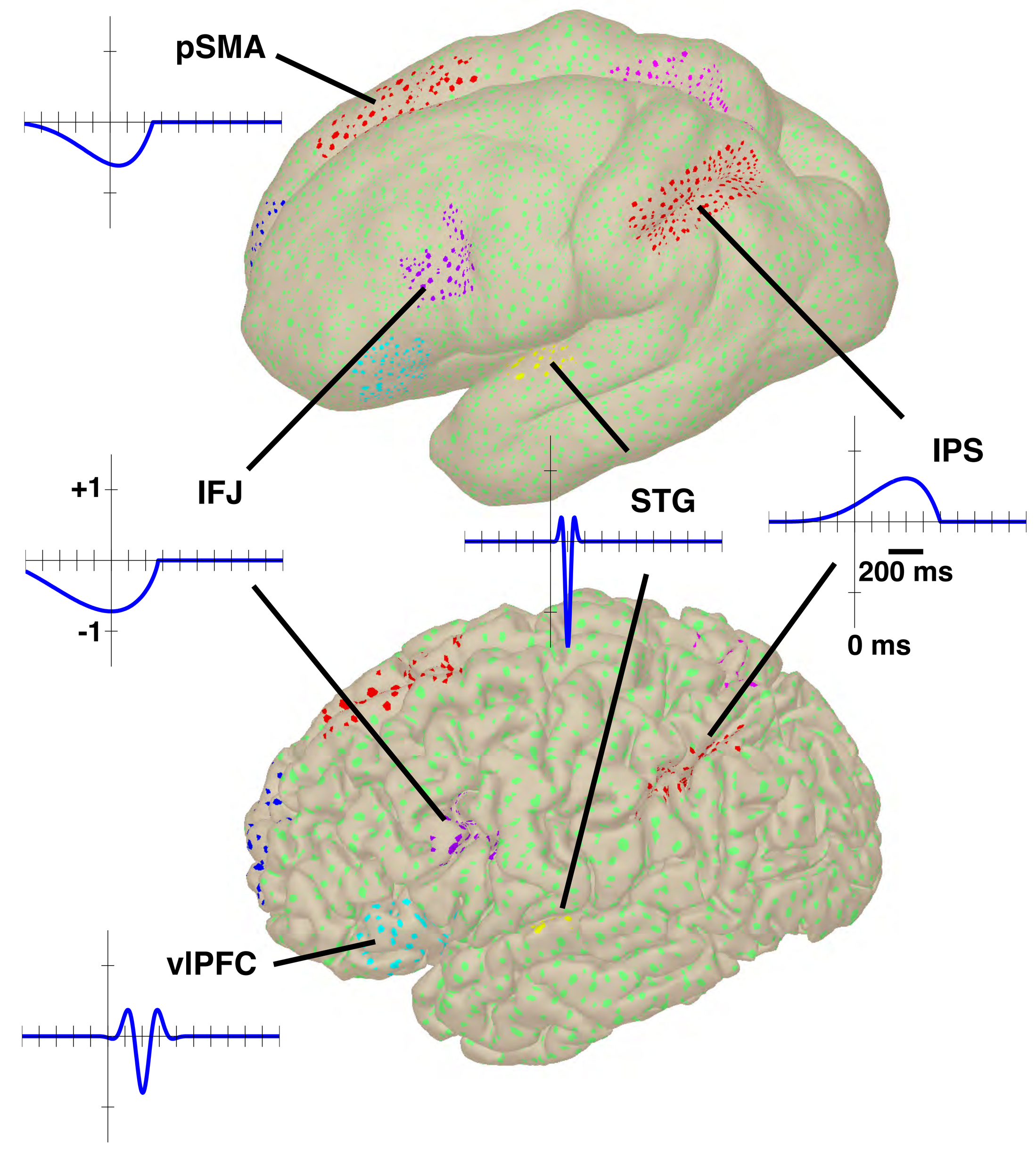

Figure 3. Partially inflated and normally folded representations of the cortical surface of a single subject, obtained using Freesurfer. The green dots show locations at which a surface-normal dipole source could be modeled and projected through a forward operator based on a boundary element model (BEM) implemented in EMSE. Local clusters were selected in 5 regions (patches of varying color) and each dipole location within the cluster was assigned the simulated time-varying source activity waveform shown in the corresponding inset. Simulations were performed in Matlab using custom code and the forward and inverse operators estimated in EMSE.

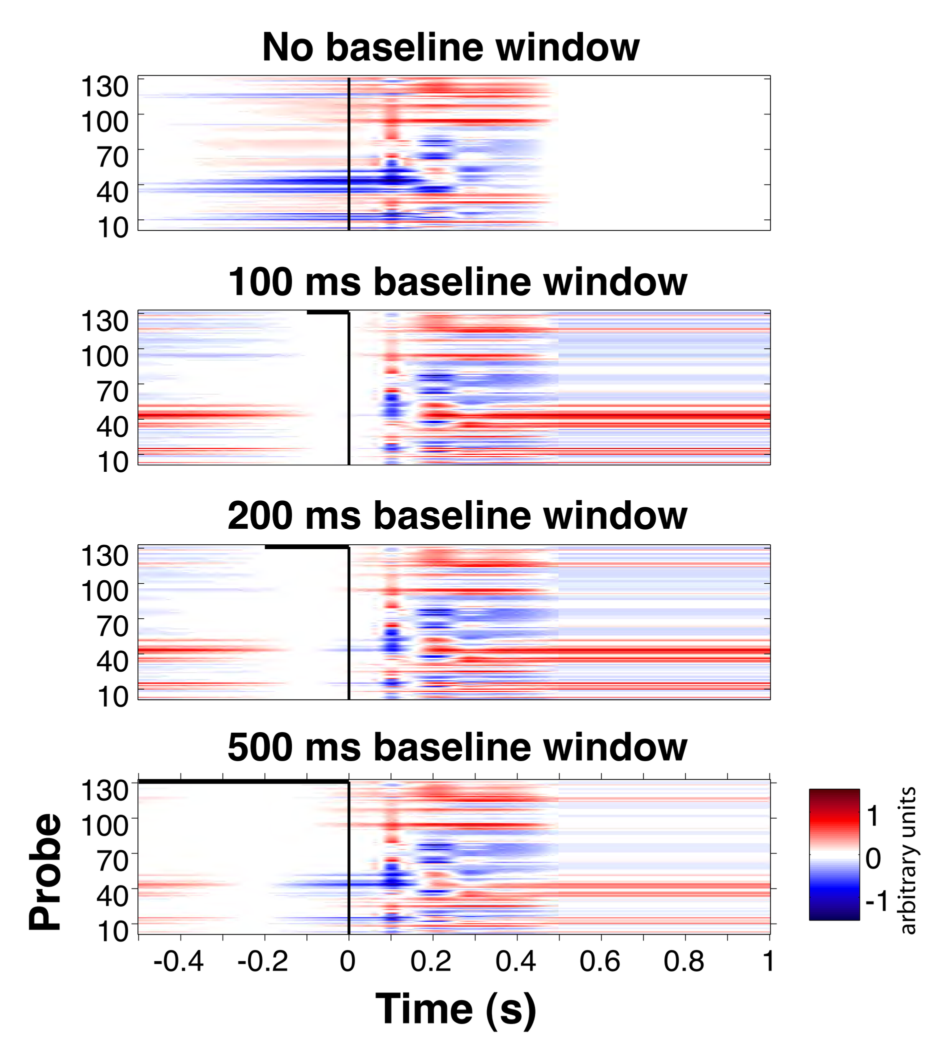

Figure 4. Time-voltage plots of simulated potentials measured at 131 probe locations distributed across the scalp. The simulated data were obtained by projecting the source waveforms shown in Figure 3 through the forward operator. The top panel shows the veridical activation pattern. The other panels show the activation patterns following within-probe subtraction of the mean voltage in the designated baseline window preceding t=0.

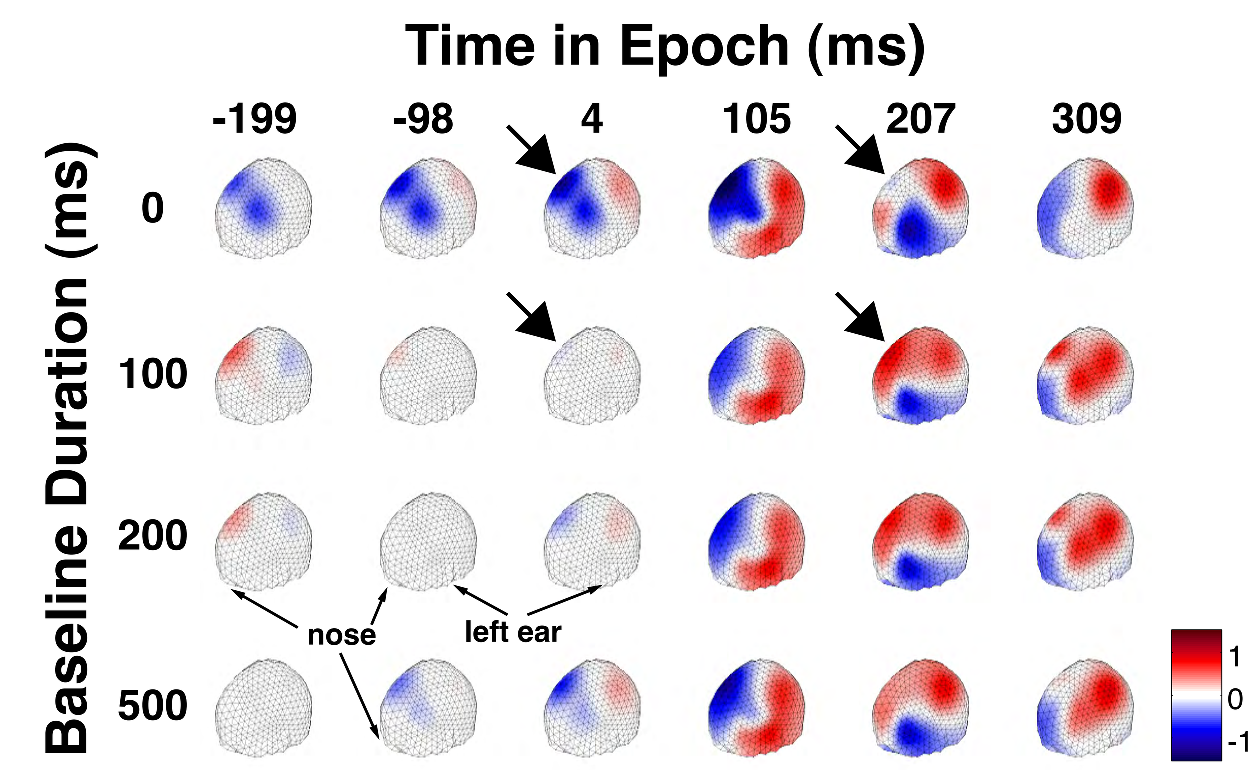

Figure 5. Time-varying scalp topographies arising from the collection of simulated sources shown in Figure 3. The top row shows the veridical topographies, whereas the other panels show the topographies following baseline correction using windows of different lengths. The arrows highlight times at which the topographical maps are distorted by the choice of baseline window. Although this example uses simulated data, it serves to make the point that whenever baseline correction is used, the resulting topographic maps (and inferred source distributions) must be interpreted relative to the source distribution that was present during, and subsequently removed, from the baseline window.

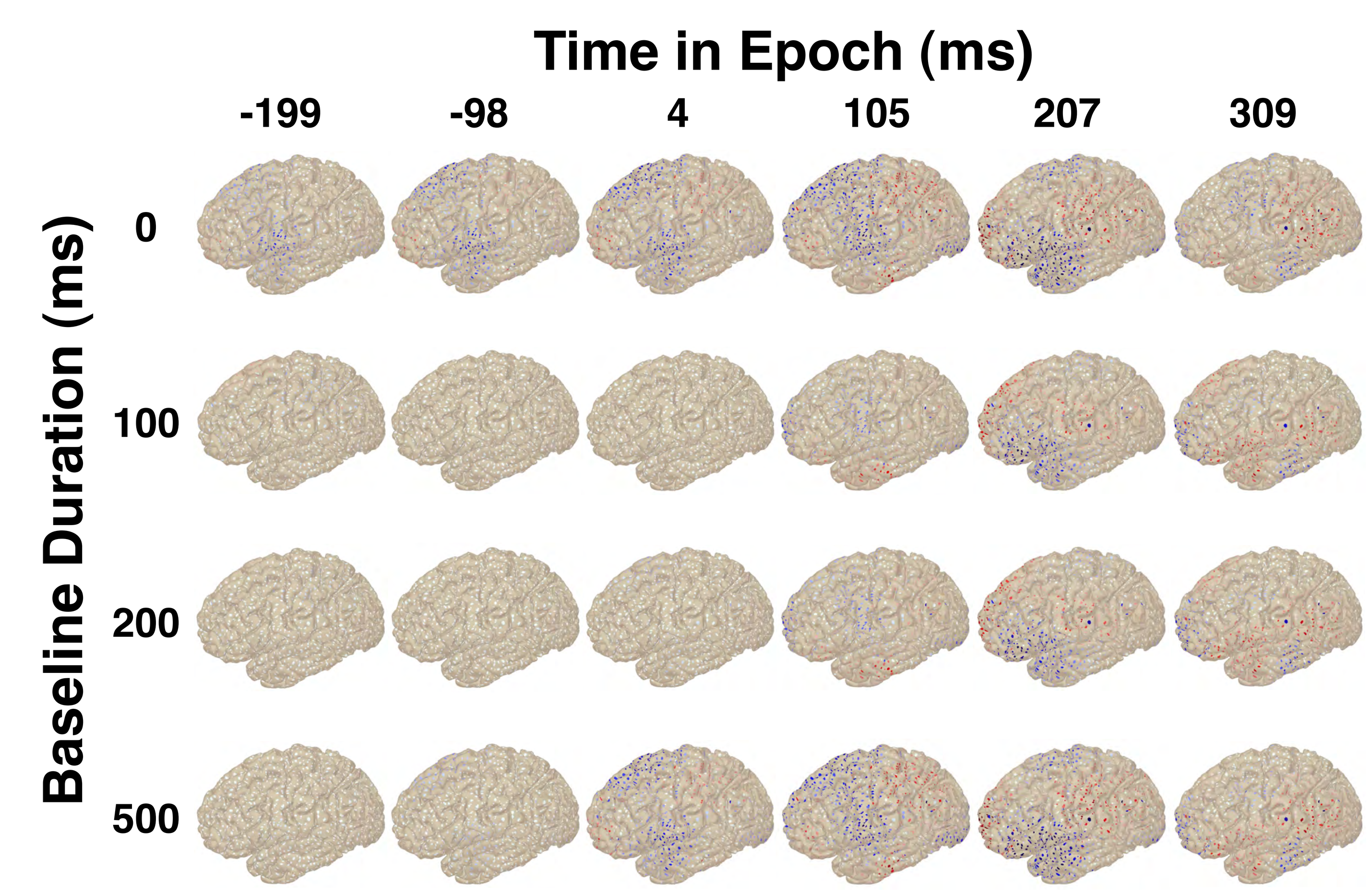

Figure 6. Projections of the estimated time-varying scalp potentials (in each of the baseline correction conditions) through a normalized minumum norm inverse operator to each of the cortical locations in the model. When compared with the original source locations shown in Figure 3, the problems of estimate splatter inherent in source location estimates become apparent. In the baseline correction conditions, sources that were originally active at t<0 are now active (with opposite polarity) at later times as would be expected given that this is a linear system.

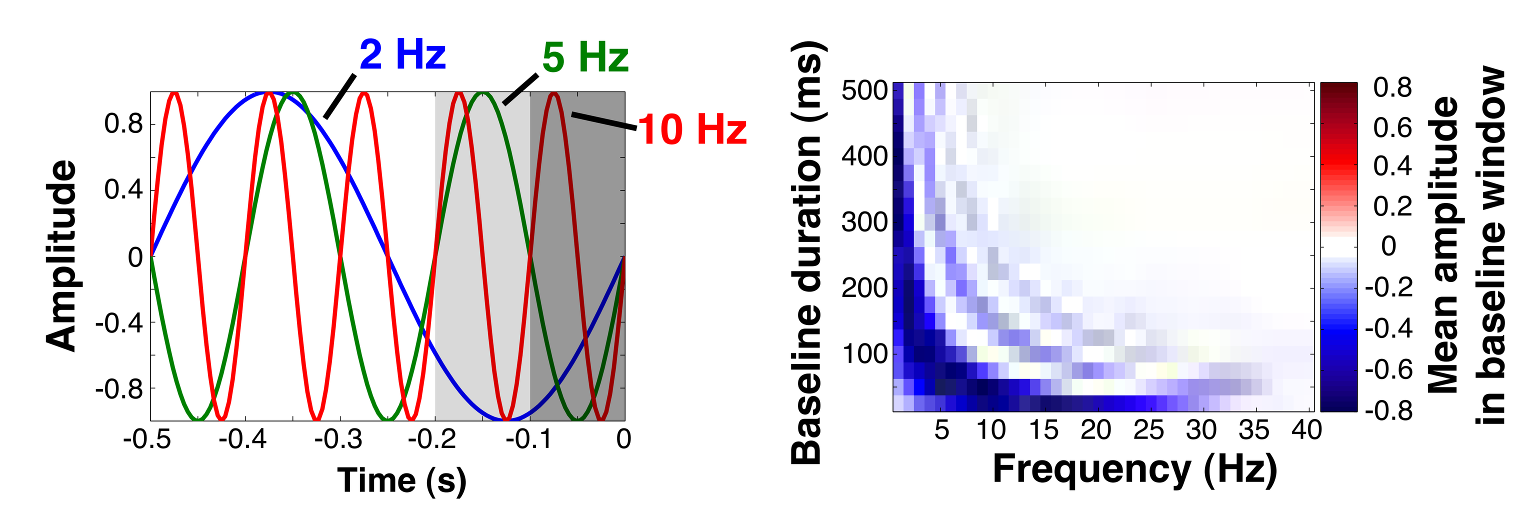

Figure 7. Baseline duration interacts with spectral properties in determining the extent to which the baseline period activity will be “projected” into the non-baseline period of the analysis epoch. Potential problems arise for processes characterized by low frequencies, e.g. the CNV, and short baseline window. The mean amplitude in a baseline window will also depend on the phase of a frequency component, but that variation is not shown here.

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