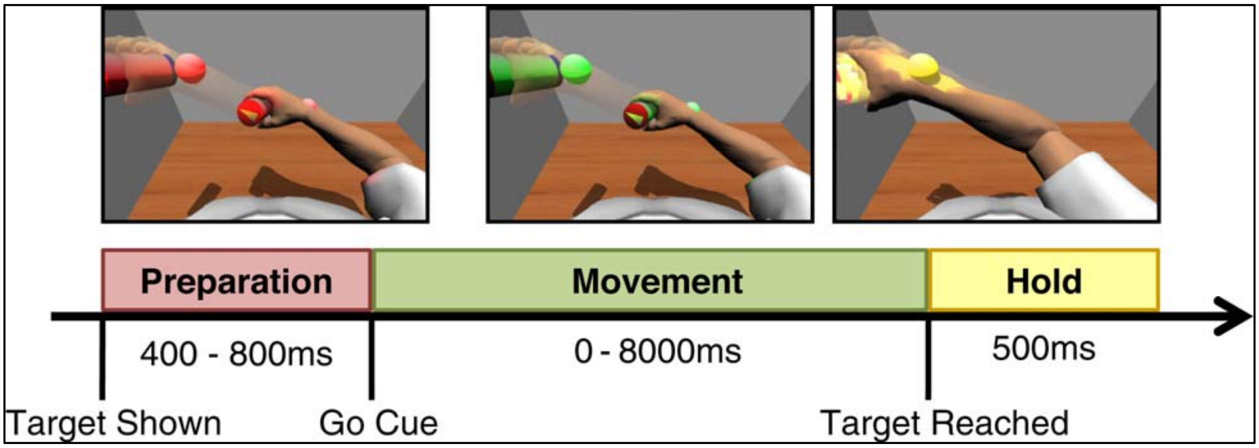
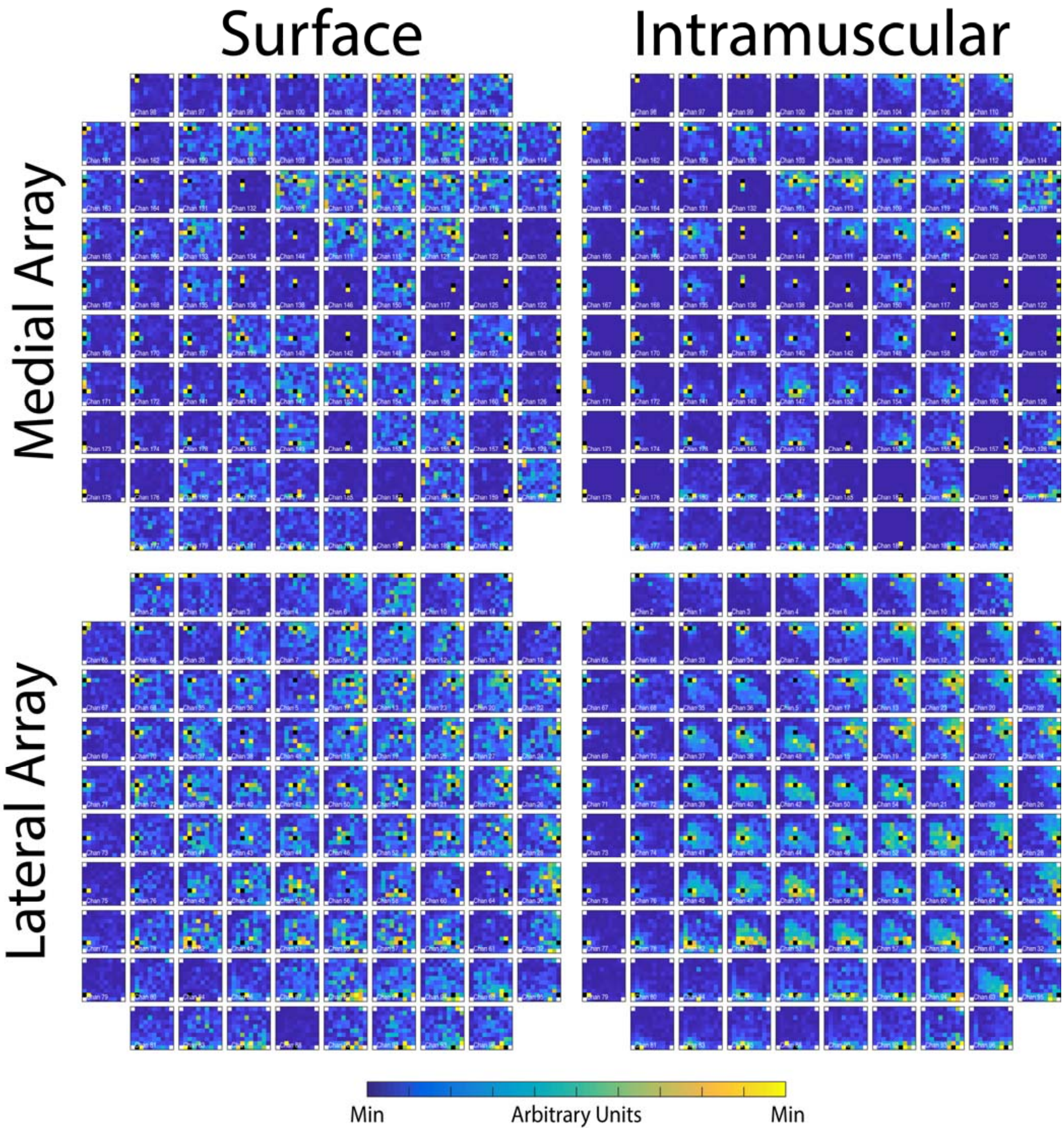
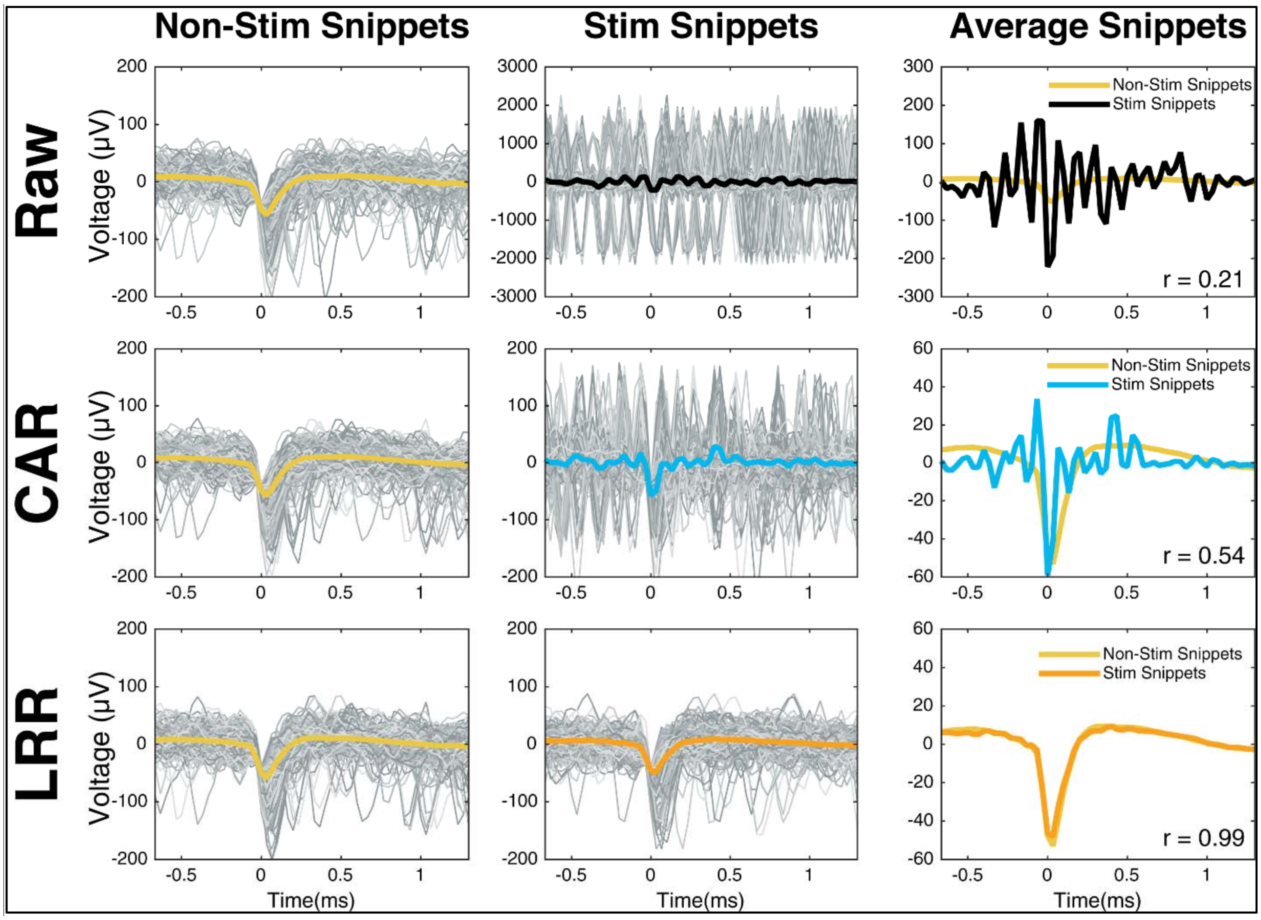
Supplement



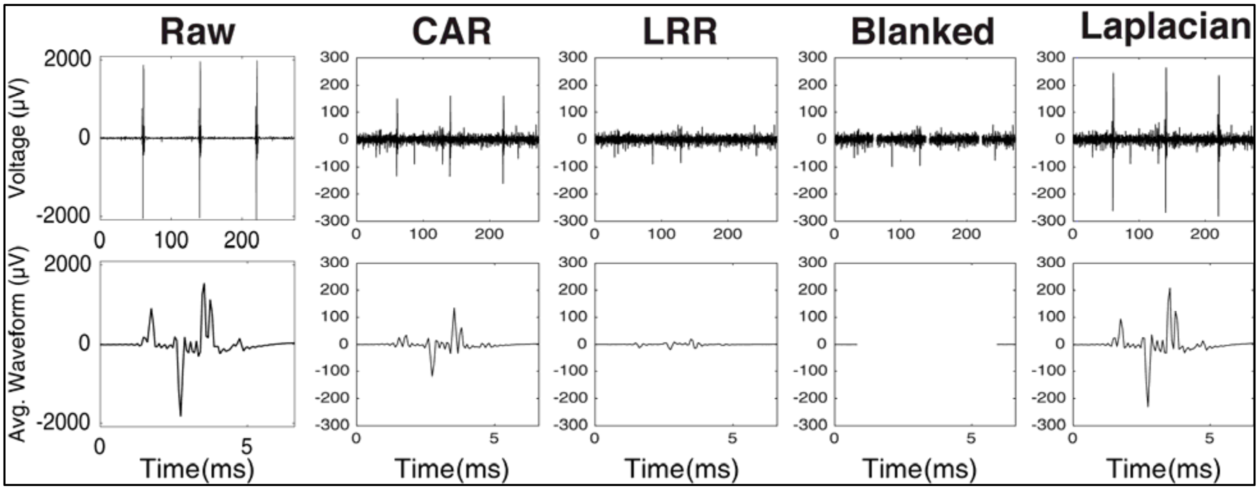
Supplementary Figure 1. *3D iBCI reaching task. T8 used 3D glasses to watch and control reaching movements in a virtual environment shown on a 3D monitor. The game was comprised of three phases: preparation to reach, movement to the target, and target acquisition. During the preparation phase, the arm was locked in place and a red target was shown to the user. He was instructed to prepare his movement to the target without willing actual movement. During the movement phase (cued via an auditory beep and changing the color of the target to green), T8 attempted to move the virtual arm towards the target. Once the iBCI-controlled arm overlapped with the target (target acquisition region shown as spheres at the wrist), the target color changed to yellow. After remaining within the target region for 500ms, the target was considered successfully acquired, a success auditory cue was played, and the next trial began.*



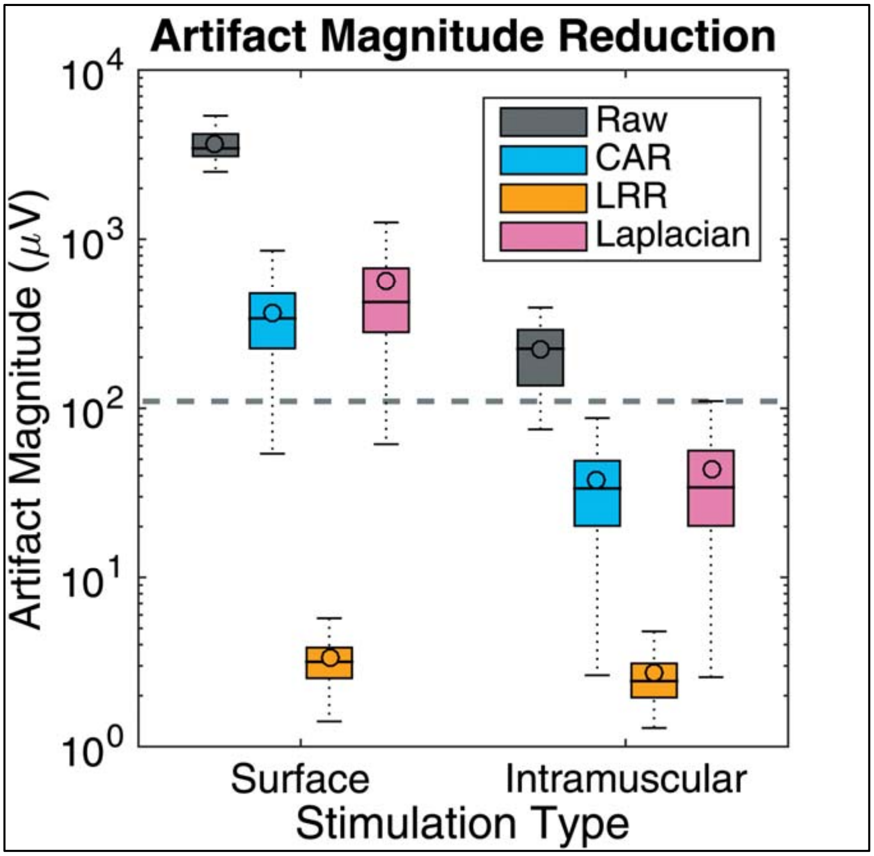
Supplementary Figure 2. *Average LRR weight matrices for both arrays and stimulation conditions. In each of the four subplots, there are 96 squares which show the LRR weights solved for a given channel (displayed topographically). Inside each of the 96 squares is a representation of the LRR coefficients for that channel, where the black square denotes the channel itself, the white squares denote the four non-functional corners, and the colored pixels represent the magnitude of the coefficients used to construct that channel's reference signal. [Left] The weights for each channel when trained on blocks with surface stimulation, shown for both arrays. [Right] The weights for each channel when trained on blocks with intramuscular stimulation.*



Supplementary Figure 3. *Threshold crossing snippets from artifact reduced neural data. For one representative channel during a surface stimulation block, 2ms windows (snippets) of neural data surrounding a subset of TX events are shown as grey traces, and average snippets are shown as thick colored lines. [Left] Non-stimulation period snippets show the normal channel activity that triggers a TX event. The average snippet waveforms appear similar between Raw, CAR, and LRR, suggesting that LRR did not distort normal spike waveforms compared to standard system settings. [Middle] Snippets of activity that triggered TX events during artifact periods. We expect spurious threshold crossings triggered by stimulation artifacts to have a different waveform than normal activity, resulting in greater snippet variability and average waveforms that differ from baseline activity. [Right] For a properly cleaned signal, the average snippet during stimulation periods (black/blue/orange lines) should be similar to the average snippet during non-stimulation periods (yellow). There were strong distortions in the waveforms that triggered threshold events for the Raw and CAR cleaned signals ($r < 0.55$). However, the LRR cleaned signal exhibited threshold crossing snippets that were very similar to the non-stimulation period snippets ($r = 0.99$).*



Supplementary Figure 4. *Artifact magnitude reduction illustrated for a representative channel, including small Laplacian performance. [Top] Neural recordings made during surface stimulation after artifact reduction and bandpass filtering. Note the larger y-axis in the raw subplot, and the reduced artifact amplitudes after artifact reduction. The blanked trace removes 5ms of data during stimulation. [Bottom] Averages of 1000+ stimulation events for each reduction technique. During blanking, no signal is shown. For this channel, small Laplacian spatial filtering yields artifact magnitudes that are reduced compared to raw, but larger than both CAR and LRR.*



Supplementary Figure 5. *Distribution of the artifact magnitudes for each stimulation and artifact reduction condition during single-electrode stimulation blocks – with small Laplacian spatial filtering performance included. Data includes one point per channel (192 total) per block (6 surface and 4 intramuscular blocks). Colored bars represent the interquartile range, horizontal lines represent the median, colored dots represents the mean, and dotted lines extend to the maximum and minimum nonoutlier values (defined as points outside 1.5x the inter-quartile range). Across all blocks and channels, small Laplacian artifact magnitudes are similar to those achieved by CAR, but much larger than those resulting from LRR artifact reduction.*

Supplementary Section 1

Here, we derive the simple equation used to model performance degradation as a function of the amount of data blanked. In the equations that follow, we denote the decoder output as Y, the true signal as X, and the Noise as $\varepsilon \sim N(0,\sigma^2)$.

One measurement can be modeled as:

$$Y_n = X + \varepsilon_n$$

So averaging over multiple measurements yields:

$$\bar{Y} = \frac{1}{n}\sum_{i=1}^{n}(X + \varepsilon_i)$$

$$\bar{Y} = X + \frac{1}{n}\sum_{i=1}^{n}(\varepsilon_i)$$

$$Var(\bar{Y}) = Var(X + \frac{1}{n}\sum_{i=1}^{n}(\varepsilon_i))$$

$$Var(\bar{Y}) = \frac{1}{n^2}Var(\sum_{i=1}^{n}(\varepsilon_i)) = \frac{1}{n^2}\sum_{i=1}^{n}\mathrm{Var}(\varepsilon_i) = \frac{1}{n^2}(n\sigma^2) = \frac{1}{n}\sigma^2$$

We define decoder SNR as:

$$SNR = \frac{1}{std(\varepsilon)} = \frac{1}{\sqrt{Var(\bar{Y})}} = \frac{\sqrt{n}}{\sigma}$$

If we define a full bin containing N points and a partial bin containing [N-m] points, which is reparametrized as $[(1-b)N]$, where the blanking coefficient b is $0 \le b \le 1$.

$$SNR_{Full} = \frac{\sqrt{N}}{\sigma}, SNR_{Partial} = \frac{\sqrt{N-m}}{\sigma} = \frac{\sqrt{(1-b)N}}{\sigma}$$

$$\frac{SNR_{Partial}}{SNR_{Full}} = \frac{\frac{\sqrt{(1-b)N}}{\sigma}}{\frac{\sqrt{N}}{\sigma}} = \sqrt{(1-b)}$$

Therefore, the decoder SNR for a bin with a blanking coefficient b is $SNR_{Blanked} = SNR(\sqrt{1-b})$.