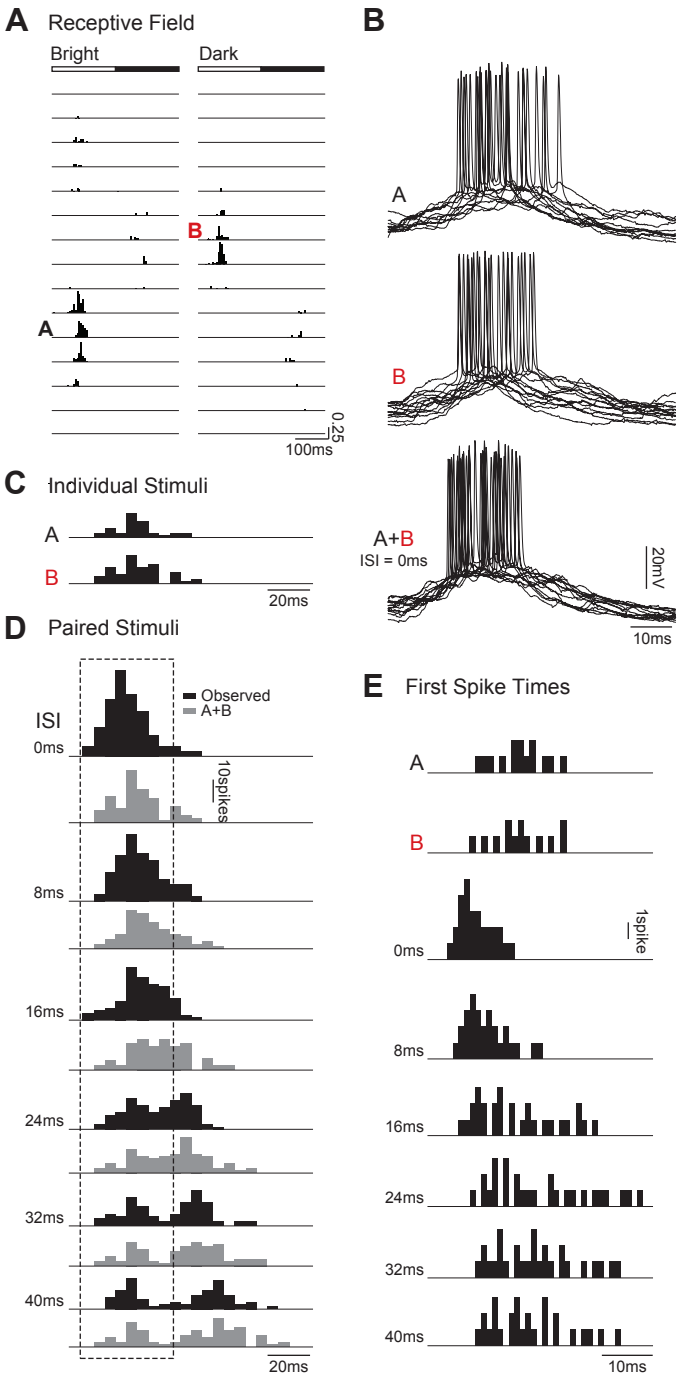

Figure S1. Additional example of nonlinear summation in a layer 4 simple cell. **A**. Optimally oriented bright and dark bars were flashed (128ms) in 16 positions across the receptive field of a layer 4 simple cell, generating a one-dimensional map of spike responses. Positions A and B were chosen as sites in two discrete subregions that evoked strong bright and dark responses, respectively. **B**. A and B each evoked spike output when briefly presented alone (16ms), but evoked more spikes with a narrower temporal distribution when presented simultaneously. **C**. PSTHs from 30 presentations of A and B alone. **D**. PSTHs of recorded responses to 30 presentations of A+B presented at varying intervals (black) were compared to predicted PSTHs calculated as the linear sum of the responses to A and B alone (gray). The summed responses were measured within a window bounded by the beginning of the response at ISI = 0ms and the end of the responses to A and B alone (dashed line). **E**. Distributions of the first spike evoked by each of 30 presentations of A and B as a function of their temporal asynchrony.

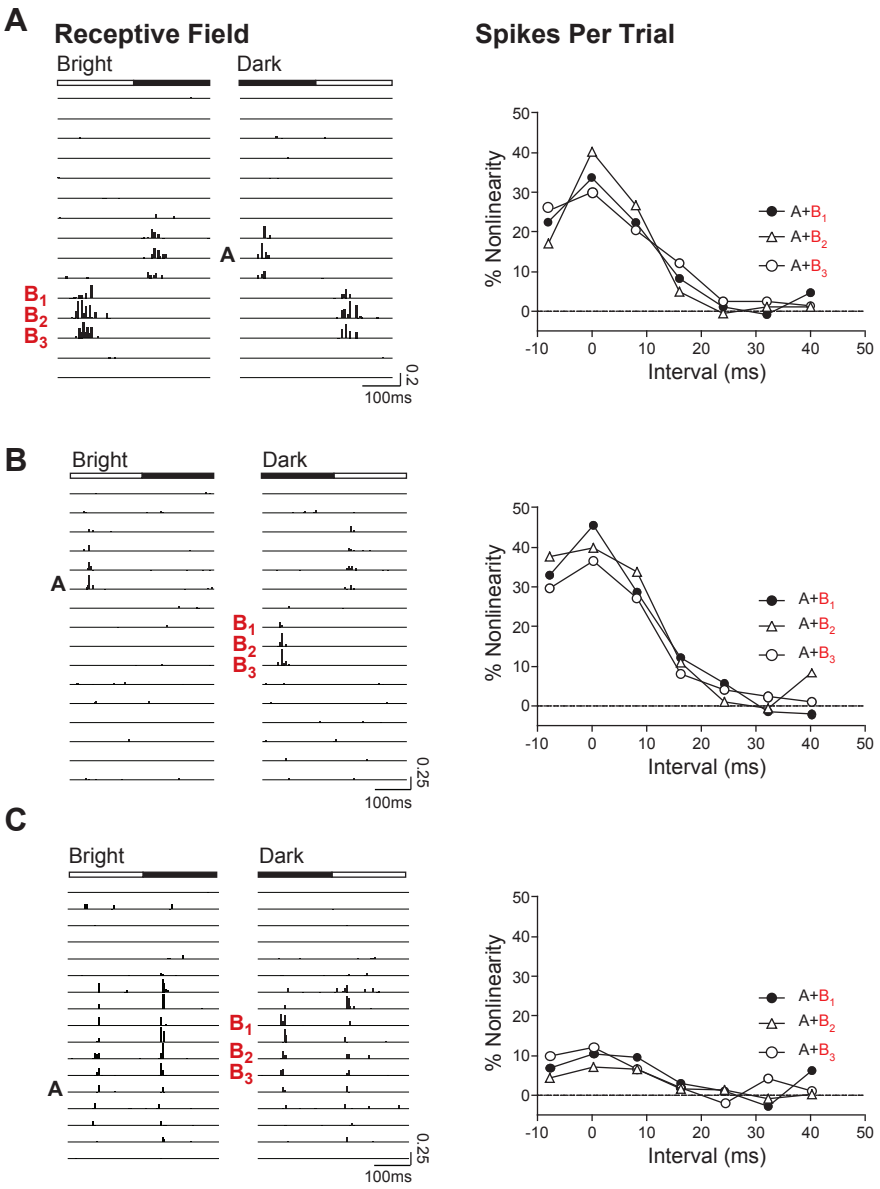

Figure S2. Summation nonlinearities do not depend on the spatial separation between stimulation sites in the receptive field. In each case, we measured the summation of spike responses to the presentation of three pairs of flashed bars, with bar A held constant. The stimulation paradigm and measurements were exactly as described for data in the main text. **A-B**. In these two simple layer 4 regular spiking neurons, both the degree of nonlinearity in spike response summation and the window for nonlinear summation (<16ms) were consistent, regardless of the distance between bars A and B. **C**. Similarly, in this complex layer 2/3 regular spiking neuron, summation was close to linear, regardless of the distance between bars A and B.

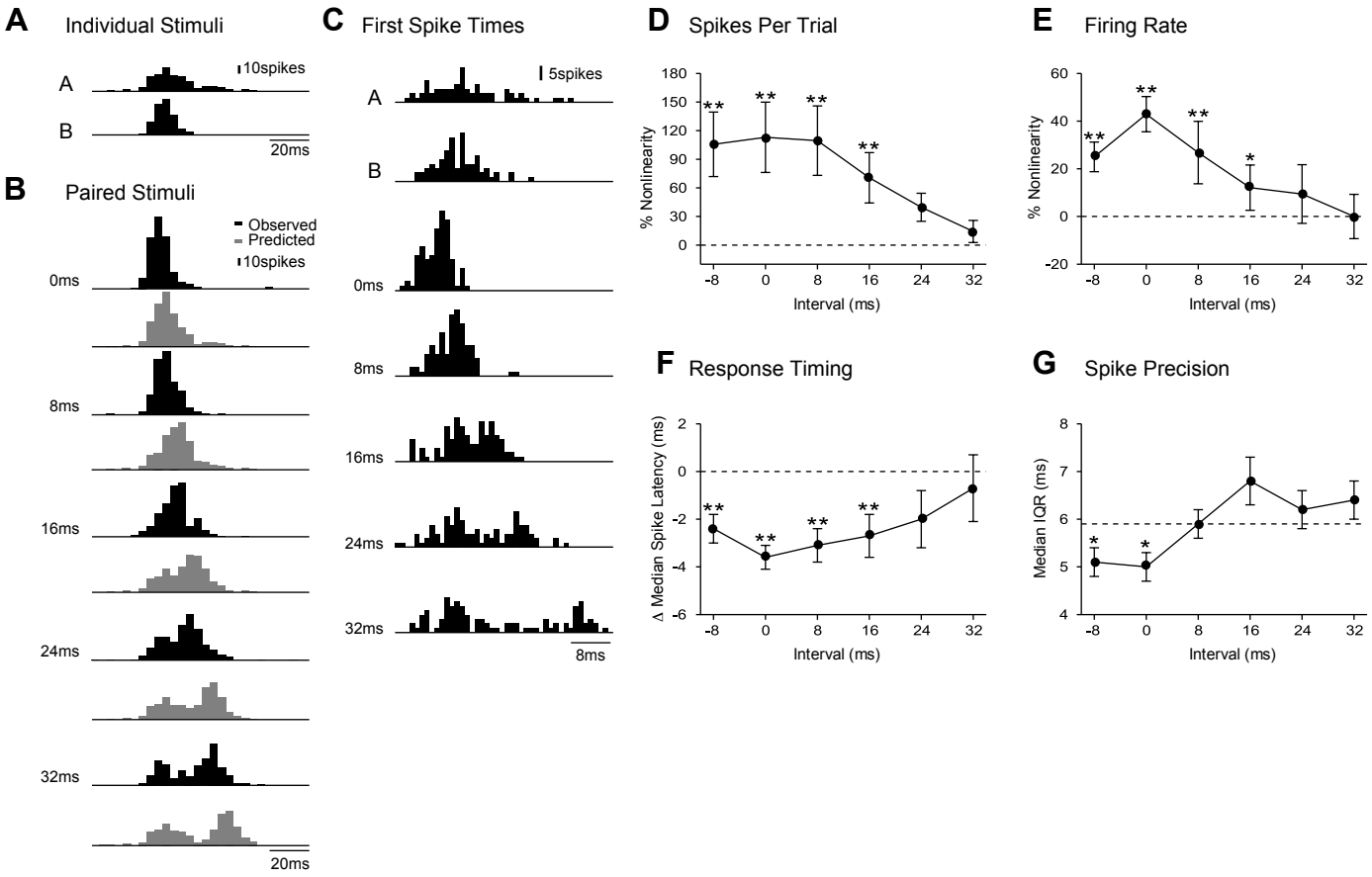

Figure S3. Temporally coincident stimuli elicited fast, strong, precise responses in extracellularly recorded layer 4 neurons. Twenty-eight layer 4 regular spiking (RS) neurons were recorded with metal electrodes in a separate series of experiments. These experiments were identical to those described in the body of the paper except that the duration of the bar presentations was limited to 8 ms. **A**. PSTHs of the responses of a layer 4 RS simple cell to 100 presentations of a bright (A) and dark bar (B). **B**. PSTHs of the responses to the paired presentations of bars A and B at different ISIs (black) compared with predicted responses (A+B) based on the temporally offset sums of responses to A and B alone. Summation was supralinear for small ISIs. **C**. Histograms of the first evoked spike on each trial showed increased precision for nearly coincident stimuli. **D-E**. The average number of spikes per trial (**D**) and instantaneous firing rate (**E**) was significantly greater than expected from linear summation for presentation of paired bars at short ISIs (0-16 ms, n = 28). These data agree well with the intracellular data from RS cells shown in Figure 5. **F**. The median spike latency was reduced at short ISIs (n = 26). **G**. The precision of spike timing was significantly increased at short ISIs (n = 26) as indicated by the decrease in the median interquartile range of spike times. Dashed line reflects the average precision in the responses to bars A and B alone.

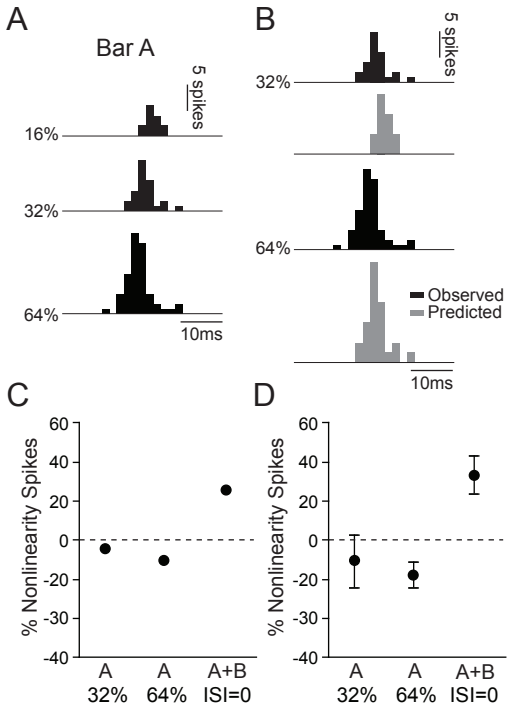

Figure S4. Increasing stimulus strength by increasing contrast does not generate nonlinear summation of responses. **A**. Spike responses of an example layer 4 cell to one flashed bar (Bar A) presented in one receptive field position at 3 contrasts. **B**. The response to the bar at low contrast was used to predict the response to the same bar at higher contrasts, assuming linear summation in response to increasing contrast. For example, if summation is linear, the 32% contrast response would be predicted to be twice the magnitude of the 16% contrast response. Observed responses to Bar A are shown in *black*, predicted responses in *gray*. In each case, the observed response was equal to or smaller than the predicted response. **C**. Data from the example cell shown in panels A and B. Measurements of linearity were made as in Figures 1 and S1. The responses to the flashed bar at 32% and 64% contrast, measured as spikes/trial, were smaller than the predicted amplitude. The *dashed line* at 0 indicates the predicted amplitude. In contrast, the response to Bar A paired with a second bar in a different receptive field position (Bar B) at ISI = 0ms was larger than predicted. **D**. Population data from flashed bar stimuli at varying contrasts (n = 6 layer 4 cells). Increasing the contrast of the single bar stimulus led to linear or sublinear summation, whereas paired bar stimuli A+B at ISI = 0ms evoked supralinear spike responses.

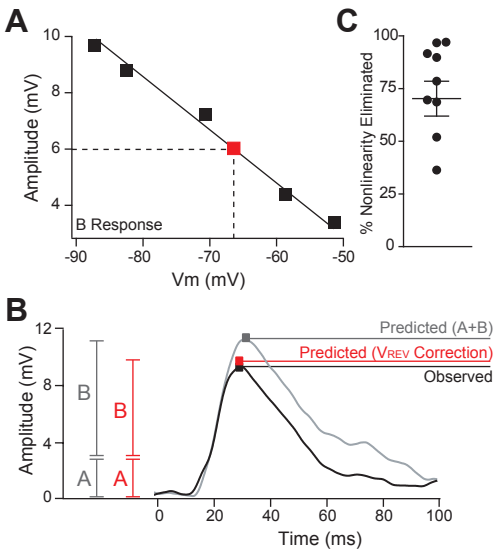

Figure S5. Sublinearity of Vm summation partly results from changes in driving force. One possible explanation for the sublinearity of the membrane potential response to paired stimuli is that when the synaptic response to bar B occurs simultaneously with that to bar A, the driving force on the response to B may be decreased because the Vm is already depolarized by the response to A (Higley and Contreras, 2005). To test this hypothesis, we recorded the response to B at five Vm levels in the presence of QX-314 and used the linear relationship between Vm and PSP amplitude to predict the response to B, starting from the Vm at the peak of the response to A. We then used this corrected estimate to predict the amplitude of the response to A+B, assuming linear summation. **A**. Responses to flashed bar B were recorded at five Vm levels (*black squares*), and the linear relationship between Vm and response amplitude was used to calculate the expected amplitude of the response to B, given that it started from the peak Vm of the response to flashed bar A (*red square*). **B.** The peak of the average recorded Vm response to bars A+B together at ISI = 0ms (*black*) was smaller than the expected response calculated as the linear sum of the responses to A and B alone (*gray*). However, the observed response agreed well with the adjusted prediction generated by accounting for the decrease in driving force due to depolarization (*red*). **C.** Across the population of 9 layer 4 simple cells, the revised estimation accounted for 61.6 ± 12.6% of the observed sublinearity remaining after spikes were eliminated.

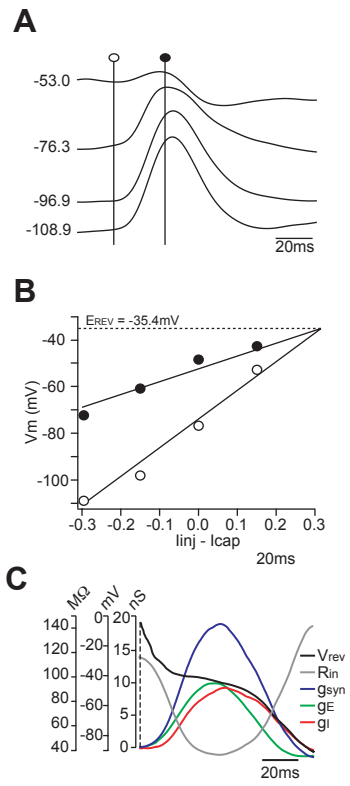

Figure S6. Calculation of synaptic conductances for example ISI=0 data in Figure 7. **A**. Each stimulus presentation was given repeatedly while holding the cell at varying membrane potential levels. **B**. The membrane potential at points before (*open circles*) and during (*black circles*) the synaptic response was measured at each holding potential and a line was fitted to the data for each condition, taking into account an adjustment for the capacitative current. The intersection point of these lines indicates the reversal potential for this point (*black circle* in **A**) in the synaptic response. **C**. The reversal potential (Vrev; *black*), input resistance (Rin; *gray*), and total synaptic conductance (gsyn; *blue*) were calculated from these data, and the Vrev at each point was used to divide the gsyn into the component excitatory (gE; *green*) and inhibitory (gI; *red*) conductances.

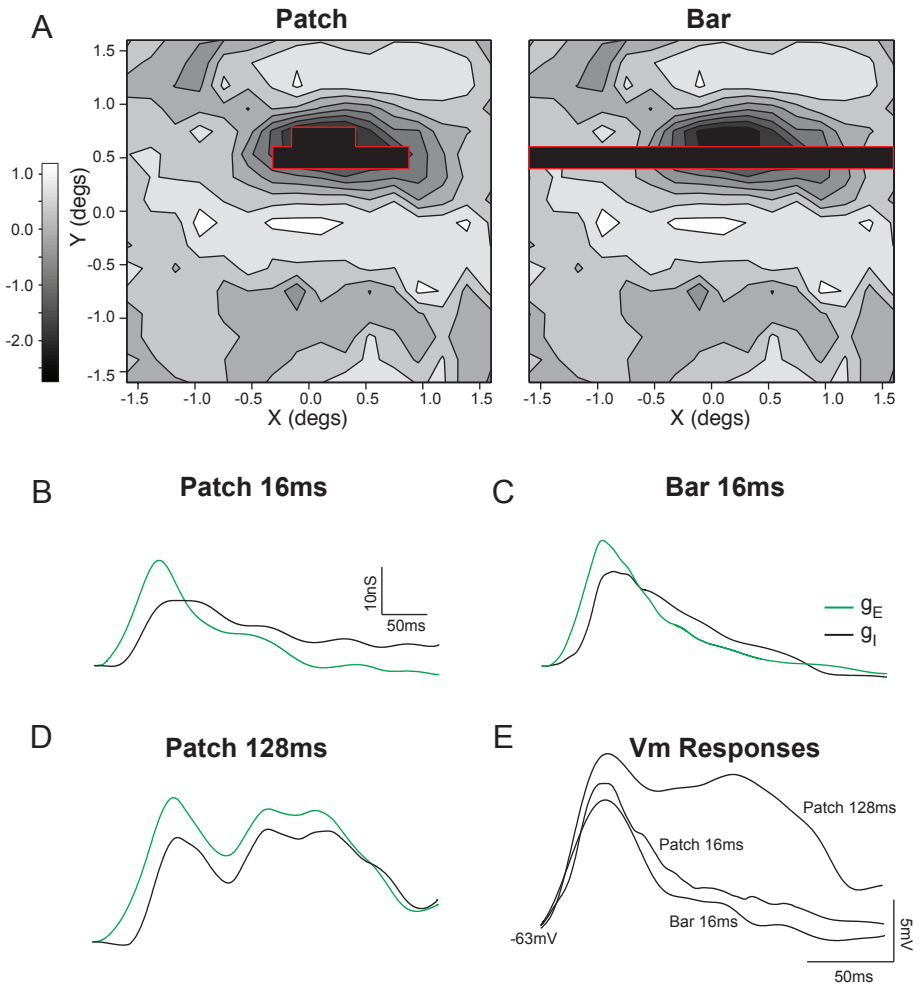

Figure S7. Briefly flashed patch and bar stimuli evoke a similiar pattern of excitatory and inhibitory conductances. **A**. Receptive field map of the example cell shown in Figure 1. Two dark stimuli were presented in the large, dark-excitatory subregion of the receptive field. We compared the responses to a dark patch stimulus of 90% contrast in the center of the subregion (left), and a dark, optimally oriented bar of 90% contrast in the same position (right). The conductances underlying the observed membrane potential responses were calculated as described in Figure 7 and Supplementary Figure 6. **B**. The patch stimulus (16ms duration), evoked an increase in excitation (gE; green), followed rapidly by an increase in inhibition (gI; black). **C**. The bar stimulus (16ms duration) evoked a very similar pattern of gE followed by gI. **D**. Importantly, when the duration of the patch stimulus was increased to 128ms, the window between the onsets of the evoked gE and gI did not change. These results suggest that the observed increase in gI is not a result of the off response at the end of the flashed stimulus, but is instead a component of the initial synaptic response to the stimulus. The peak amplitude and overall duration of the evoked conductances were increased in comparison to the 16ms stimulus condition. Scale in C and D is as in A. **E**. Overlaid membrane potential traces of the responses to each stimulus condition.