Differences in spike waveform adaptation between broad and narrow spiking neurons in Area V4 of the awake macaque

NN4

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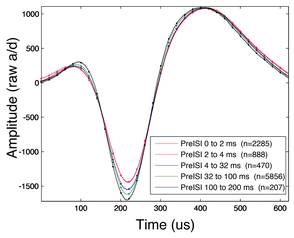
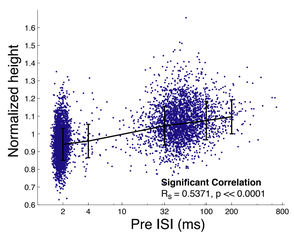
Introduction

1) The neocortical circuit is comprised of neurons that differ markedly in their biophysical properties, which is reflected in the shape of extracellular action potentials.
2) Here, we distinguish between broad spiking (putative pyramids) and narrow spiking (putative fast-spiking) neurons, and find that the different spike adaptation properties of these populations are consistent with those described in the intracelluar literature.
3) We also use spike adaptation as a window into the internal state of individual neurons, to test novel hypotheses about the neural mechanisms of attention.
4) Consistent with the hypothesis that attention depolarizes neurons, we find attention-dependent reductions in spike height and burst firing.

Waveform shape depends on spike history

Action potential height adaptation arises largely from cumulative inactivation of voltage-gated sodium channels during previous action potentials (Colbert et al., 1997; Martina and Jonas, 1997; Remy et al., 2009).



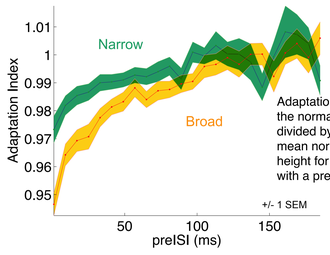


Hypothesis 1: Narrow spiking neurons should show less spike adaptation than broad

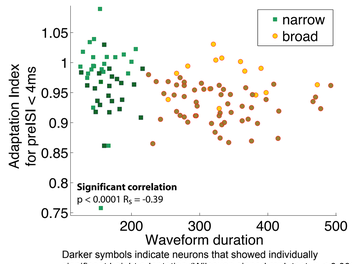
Why would we predict this?

While most cortical neurons exhibit spike height and frequency adaptation, fast-spiking inhibitory inhibitory interneurons (FS) undergo little or no adaptation (McCormick et al., 1985; Martina and Jonas, 1997; Gonzàlez-Burgos et al., 2005). If our narrow spiking population largely corresponds to FS neurons, then we would expect less adaptation within this population.

Stronger spike height adaptation among broad spiking neurons

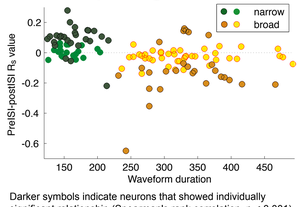


Adaptation Index is the normalized height divided by the mean normalized height for all spikes with a preISI > 100ms



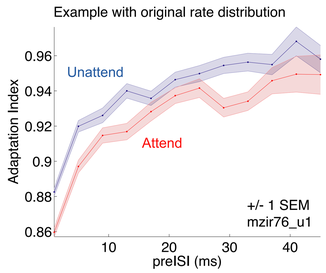
Darker symbols indicate neurons that showed individually significant height adaptation (Wilcoxon signed rank test, p < 0.001).

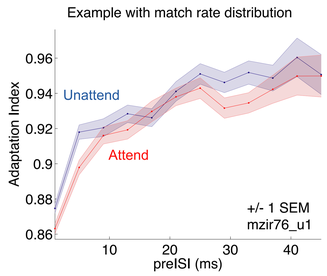
Stronger spike frequency adaptation among broad spiking neurons

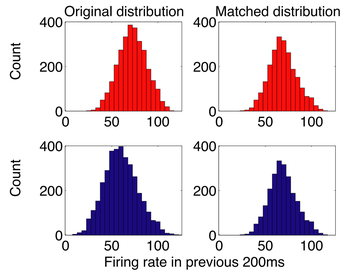


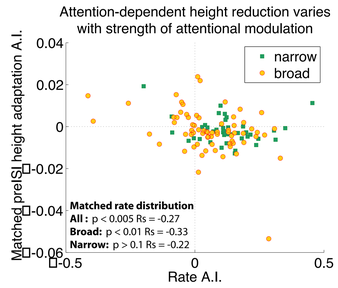
Darker symbols indicate neurons that showed individually significant relationship (Spearman's rank correlation, p < 0.001).

Hypothesis 2: Attentional feedback depolarizes neurons, reducing spike height



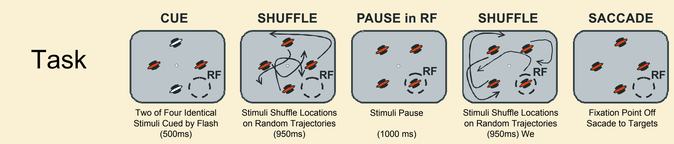


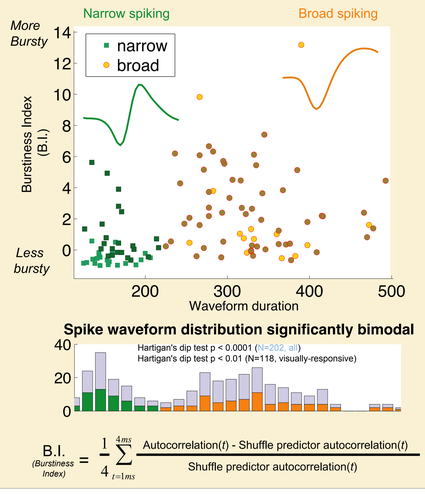




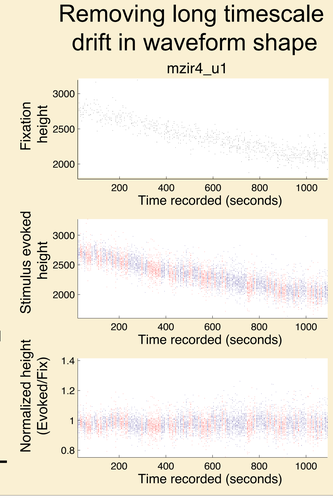
We find a significant reduction in action potential height with attention even after controlling for the amount expected from the attention-dependent elevation in rate (Wilcoxon signed rank test; entire population, p < 0.005, narrow spiking neurons, p < 0.05, broad spiking neurons with significant increases in rate with attention, p < 0.05).

Methods

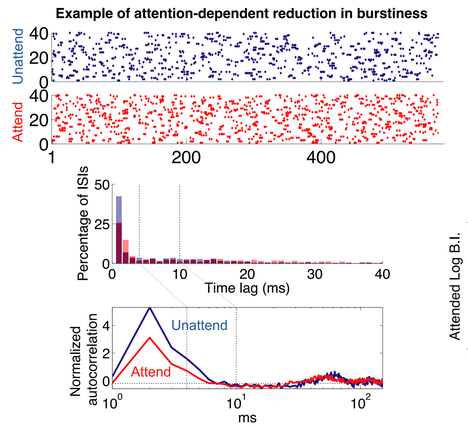




Removing long timescale drift in waveform shape

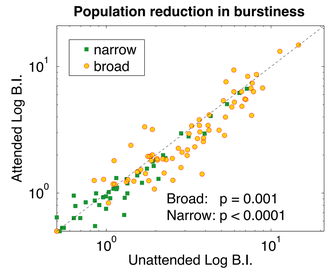


Hypothesis 3: Attentional feedback depolarizes neurons, reducing burstiness



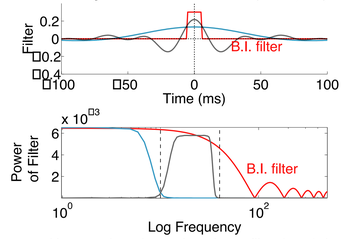
Why would we predict this?

Previous studies have shown that depolarization reduces burst firing in pyramidal neurons (Wang and McCormick, 1993; Steriade et al., 1993, 1998, 2001.)



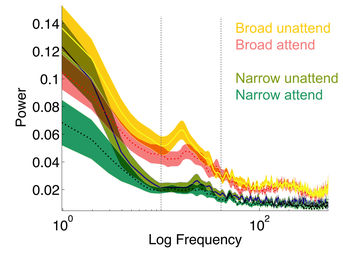
Reductions in low frequency power do not explain reduction in burstiness with attention

The burstiness index is senstive to low frequency changes in the autocorrelation (below, red).

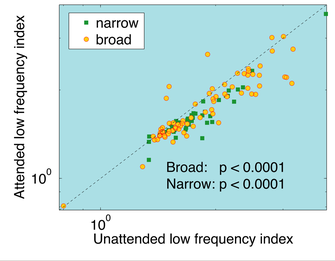


Here, we introduce a burstiness filter (gray) that considers bursts without low frequency contamination.

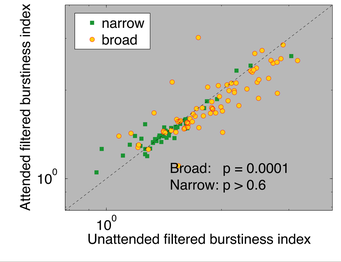
Could reductions in B.I. with attention reflect the reductions in low frequency power reported by Mitchell et al. (2009)?



Low frequency reductions among narrow and broad



Reduction in burstiness only among broad



Conclusion

1) Measurement of spike waveform adaptation provides a window into the internal channel dynamics of neurons in the awake behaving macaque.
2) Consistent with intracellular studies, we find that narrow spiking neurons show less spike height and frequency adaptation than broad spiking neurons.
3) Consistent with the hypothesis that attentional feedback depolarizes neurons, we find attention-dependent reductions in spike height.
4) This led to the novel to the novel discovery that attention reduces burst firing.

References

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