

Generic noise-enhanced coding in neural populations

Nigel G. Stocks

School of Engineering, University of Warwick, Coventry CV4 7AL, UK
ngs@eng.warwick.ac.uk
<http://eng.warwick.ac.uk/staff/ngs>

Abstract

One of the many remarkable features of sensory neurones is that, typically, they only display output signal-to-noise-ratios (SNRs) of order 0dB[1]: quite simply this implies that the neural code contains equal amounts of signal and noise. The effect of the noise is well known - it gives rise to a large degree of variability in the temporal spiking patterns observed between repeated trials.

From an engineering point of view this level of noise is nothing short of astonishing. Man-made high-fidelity signal processing systems – such as a good quality music centre – often boast output SNRs in excess of 80dB. This helps to put the level of biological observed noise in context – it is some 100,000,000 times larger than that achievable in state-of-the-art engineering systems. How biological sensory systems function with this quantity of noise, and what role the noise plays in the neural code, is still largely unknown.

A recent suggestion is that the noise plays a positive functional role in signal detection/encoding through an effect known as stochastic resonance (SR) [2]. Indeed, SR - an effect whereby the addition of noise can lead to an enhancement of a system's response to a weak signal – has been observed in real neurophysiological experiments[2]. However, in practice, SR is a rather sub-optimal method of signal enhancement and occurs only if the signal is weak i.e. it is subthreshold. For suprathreshold signal levels SR does not occur and, hence, the addition of noise only serves to reduce performance[3]. Consequently, the role of the noise has to be interpreted as a compromise – it enhances the detection of weak subthreshold signals at the expense of reduced performance for stronger, suprathreshold signal levels.

In this presentation it is demonstrated that this compromise may not be necessary. A novel form of SR termed suprathreshold stochastic resonance (SSR)[4] – is introduced and discussed. Unlike conventional SR, SSR is observed to occur for arbitrary signal levels and independent of the setting of the neural threshold. In short, SSR is observed to occur for all parameter settings and hence can be regarded as a *generic* effect. Additionally, the level of noise for which the SSR effect (and hence the transmitted information) is maximised is observed to be in the correct neurophysiological range i.e. it yields an output SNR for a single neurone of approximately 0dB. These results therefore give weight to the notion that the biologically observed levels of noise may well have purposely evolved and are not simply due to biological limitations.

References

- [1] F. Rieke *et al* (1997), “Spikes: exploring the neural code” MIT Press.
- [2] L. Gammaitoni, P. Hanggi, P. Jung and F. Marchesoni *Rev. of Mod. Phys.* **70**, 223 (1998); *Stochastic Resonance, Signal Processing and Related Phenomena*, ed. Mannella, R. and McClintock, P. V. E., *Nuovo Cimento Soc. Ital. Fis.* **17D**, 653 (1995).
- [3] N. G. Stocks (2001), “Information transmission in parallel arrays of threshold elements: suprathreshold stochastic resonance”, *Phys. Rev. E*, **63**,041114-1.
- [4] N. G. Stocks (2000), “Suprathreshold stochastic resonance in multilevel threshold systems. *Phys. Rev. Lett.* **84**, 2310.