On Natural Statistics in Multisensory Integration

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Multisensory neurons in the deep layers of the superior colliculus (DSC) integrate different sensory modalities, responding more strongly to spatially congruent inputs from distinct modalities than to input from a single modality (cross-modal enhancement, or CME) [1]. Multiple stimuli presented within a unimodal receptive field, however, evoke a weaker response than a single stimulus presented in the same receptive field (modality-specific suppression, or MSS) [2]. Although CME and MSS have been widely studied experimentally, the mechanisms underlying these responses remain unclear. As sensory neurons, multimodal DSC neurons may employ the same adaptive processes as unimodal neurons earlier in sensory pathways by adapting to the statistical properties of their inputs (cf. [3]) through processes such as gain control and firing threshold adjustment. Here we report, from a theoretical perspective, on the role that input statistics may play in multisensory neurons.

We have analysed a representative model of multisensory integration that focuses particularly on the role of input statistics [4]. This model generates CME and MSS for multivariate Gaussian inputs in a parameter regime in which all modalities have identical variance σ_0^2 in their firing rates when firing spontaneously. If the covariance between spontaneously firing inputs is close to σ_0^2, then the model exhibits MSS in the presence of evoked, stimulus-driven firing. The model thus exploits a parameter regime in which the spontaneous activity covariance matrix is close to singular. As a result, the model's behaviour is exquisitely sensitive to the choices of statistical parameters and the intensities of cross-modal inputs.

It is known that a thresholded, saturating response function is entirely sufficient to generate CME and the associated phenomenon of inverse effectiveness. We propose that DSC neurons adapt their response functions according to their input statistics through gain control and threshold adjustment. We approach this by first deriving an adaptation rule for unimodal sensory neurons, and then extending the rule to multimodal neurons. The resulting model has the virtues of simplicity and ease of neuronal implementation, and it may shed light on the underlying information processing principles of sensory neurons. Moreover, our model produces robust, testable predictions about the impact of changes in input statistics on CME in DSC neurons. The model could therefore be invalidated, in contrast to some other models that fail to make robust predictions.

References

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