Mixing Modalities Is More Than Meets the Eye Alone. Focus on: “Multisensory Versus Unisensory Integration: Contrasting Modes in the Superior Colliculus”

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The processes and mechanisms whereby individual neurons integrate and compute converging synaptic information from multiple sources remains as one of the more intriguing issues in experimental cellular and computational neuroscience. Nowhere are these issues more clearly relevant to understanding a tractable set of integrative neurophysiological and behavioral questions than in the realm of multi-sensory integration. In this issue of the Journal of Neurophysiology (p. 3193–3205), Alvarado and colleagues make a significant contribution to this field by carefully evaluating the interactive responses of neurons in the superior colliculus in response to paired stimuli arising from either the same sensory modality or across modalities. Most interestingly, the same neuron will often respond to unimodal paired stimuli with simple linear (or even sub-linear) interactions while responding to cross-modal inputs in a supralinear fashion. Although the phenomenon of multisensory super-additivity, particularly when the modality specific stimuli are weak, has been described previously (Meredith and Stein 1983; Stanford et al. 2005), heretofore there has not been a systematic experimental exploration of the nature of the differences in the computational processes for individual neurons for within and between modality processing. The experiments by Alvarado et al. were performed by recording the evoked spike activity from individual deep layer superior collicular neurons in anesthetized adult cats in response to individual modality visual, auditory, and combined stimuli both within and between sensory modalities. The results are derived from just under 100 neurons of which about half were multisensory and half were unisensory.

Interestingly, the responses of both unisensory- and multisensory stimuli to within-modal stimuli (e.g., 2 visual stimuli) were similar in their lack of super-additive responses, whereas the same multisensory neurons responded to cross-modal inputs in a generally super-additive fashion. These experiments directly address one of the central questions of multi-sensory integration—do the integrative properties that facilitate multimodal responses of neurons and thus the behavioral salience of multimodal sensory cues arise from particular intrinsic properties of the individual multisensory neurons or from the local network properties in which the multisensory neurons are imbedded? The authors’ argue for the latter hypothesis—that is, if there were fundamentally different intrinsic properties of multisensory neurons, their integration of multiple modality inputs that are super-additive should extend to their integration of unisensory inputs. This was not the case. Moreover, this finding was also consonant with their observation that additive or sub-additive integration of multiple inputs by unisensory neurons was more similar to integration of multiple inputs by multisensory neurons than was the integration of unisensory versus multisensory inputs by multisensory neurons.

The authors’ study provides new rich data for enhancing simulations of multisensory integration by individual neurons imbedded within synaptic networks. Even more intriguing are the experiments suggested by the results. Although much of the leading research into multisensory processing has been carried out in the intact brain where the spiking responses of individual neurons, particularly in the superior colliculus can be studied in response to stimuli that access the sensory apparatus, there is a growing appreciation for the importance of complementing these studies by probing the biophysical and synaptic properties of these cells and the synaptic networks in which they are contained. Armed with evidence that there are differences in individual neuron’s responses to unimodal and cross-modal stimuli, there should be opportunities for new efforts to uncover exactly how these processes are instantiated at the circuit level. Such studies should benefit from the application of modern cellular imaging, multiple electrode recording and refined subcellular neuroanatomical analysis of the sites of various inputs to multisensory collicular neurons (Skaliora et al.). These studies will still have substantial challenges as it is well established that the descending cortico-tectal projections play a major role in the multisensory properties of deep collicular neurons. However, the intriguing results of Alvarado et al. make the case for the emergence of additional supra-additive properties within the collicular circuitry, motivating additional work on the integrative properties of this fascinating structure that has a major role in sensory processing in the entire lineage of vertebrate species.

REFERENCES


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