A dynamical systems approach to multisensory integration

Bhumika Thakur[1], Abhishek Mukherjee[2], Abhijit Sen[1] and Arpan Banerjee[2]

[1]Institute for Plasma Research (IPR), HBNI, Bhat, Gandhinagar 382428, Gujarat, India
[2]National Brain Research Centre (NBRC), NH 8, Manesar, Gurgaon 122051, Haryana, India

Perception involves integration of inputs from individual sensory streams, e.g., visual, auditory and somatosensory. Merging information from different senses confers distinct behavioral advantages, for example, identification of objects is more rapid than with unimodal stimuli, especially when the signals are ambiguous. An experimental realization of the underlying complexity is captured by the "McGurk-effect"- incongruent auditory and visual stimuli eliciting perception of illusory speech sounds [1]. Time-delay between onset of auditory and visual signals (AV lag) [2] and perturbations in the unisensory streams are key variables that modulate perception. Here, we propose a dynamic systems model consisting of the basic ingredients of any multisensory processing, two unisensory and one multisensory sub-system (represented by nodes/oscillators) as reported by several researchers. The nodes/oscillators are connected such that biophysically inspired coupling parameters and time delays become key parameters of this network. The unimodal areas (auditory and visual) communicate via feedforward and feedback synapses with a third multimodal area (Superior Colliculus). The unimodal areas also communicate with each other via direct synaptic connections to simulate the anatomical convergences of visual inputs to primary auditory cortex. AV lag is captured by the time delayed interactions between the oscillators. The extent of multisensory integration is quantified by the degree of synchronization of the dynamical system represented by its order parameter. Despite its simplicity, our model is able to explain many basic properties of multisensory integration observed in the physiological literature such as cross-modal enhancement, inverse effectiveness and individual differences in multisensory temporal binding window. We also explore the effect of unreliable auditory and visual stimuli on multisensory integration by including noise in our model and by varying the strength of connections. Thereby, the dynamic model presents a quantitative framework for understanding multisensory information processing.

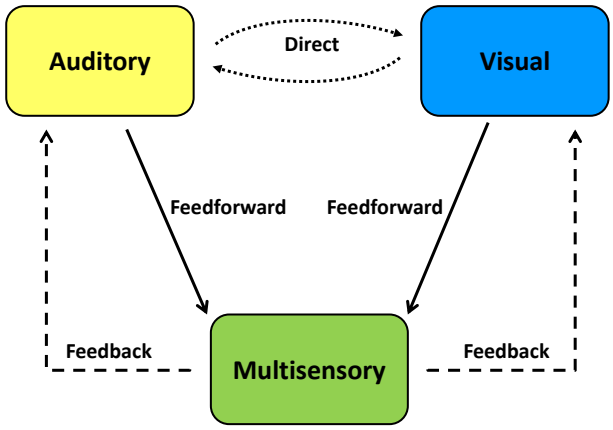

Figure 1: Dynamical model of multisensory integration.

[1] H. McGurk and J. Macdonald, Nature **264**, 746–748 (1976).

[2] K. G. Munhall, P. Gribble, L. Sacco and M. Ward, Percept. & Psychophys. **58**, 351–362 (1996).

[3] B. Thakur, A. Mukherjee, A. Sen and A. Banerjee, Sci. Rep. **6**, 31280, (2016).