Spatial and temporal congruency of multisensory integration for self-motion perception

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Robust perception of self-motion (e.g. heading), during locomotion or spatial navigation requires integration of multiple sensory cues, including vestibular and optic flow. Neurophysiological studies have revealed that multisensory heading signals are prevalent in numerous brain regions, providing potential basis for multisensory integration. However, the two modality signals frequently exhibit spatial and temporal incongruence on single neurons, generating challenges for multisensory integration efficiency. To understand exact functions of vestibular and visual signals in different brain regions, we combine psychophysics, neural recording and manipulation on awake, behaving macaque monkeys when performing various tasks. Our data reveal that on one hand, neurons in sensory-motor association areas, including posterior parietal cortex, frontal cortex, and subcortical striatum process and accumulate sensory information with different dynamics, in particular, vestibular acceleration and visual speed, suggesting that the brain uses a temporal-incongruent model for perceptual decision making across heading cues. On the other hand, neurons in more sensory areas including extrastriate visual cortex, and posterior insular cortex, frequently encode conflict spatial directions. These findings suggest that multisensory information in the brain may not always be coded in a spatial and temporal congruent way. Rather, the misalignment may benefit perception or flexible tasks under more complex contexts that involve speed-accuracy tradeoff, self- vs. object-motion recognition, and more.