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Defining a functional hierarchy of millisecond time: from visual stimulus processing to duration perception

In humans, the neural processing of millisecond time is associated with the activation of a wide range of brain areas and involves different types of neural responses. Unimodal tuning to stimulus duration, for example, has been observed in some of these areas but not in others, and its presence is either inconsistently reported or appears redundant along the cortical hierarchy. Moreover, how this duration tuning supports different functions or perception remains unclear. To address these questions, we measured brain activity with ultra-high field (7T) functional Magnetic Resonance Imaging (fMRI) while participants performed a visual duration discrimination task. Using neuronal-based modeling we estimated unimodal responses to visual durations across a multitude of cortical areas defined with high anatomical precision. In the parietal and premotor cortices, and the caudal portion of the supplementary motor area (SMA), we observed neuronal populations tuned to the full range of presented durations, spatially clustered in well-defined maps. In contrast, in the rostral SMA, inferior frontal cortex, and anterior insula, neuronal units showed duration preferences centered around the mean of the presented duration range. This preference also correlated with the perceptual boundary participants used to solve the task. Differences in preference, spatial clustering, and behavioral correlation suggest distinct functional roles for these cortical areas—ranging from abstract duration representations for readout and task-related goals in the parietal and premotor cortex, to more categorical and subjective representations in the insula and inferior frontal cortex. In line with these hypothesized roles, we also observed distinct patterns of correlation in duration preferences across these cortical regions. Overall, our findings provide a framework for a more comprehensive understanding of the neural circuits and mechanisms underlying duration processing and perception in vision.

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