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

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In humans, the neural processing of millisecond time recruits a wide network of brain areas and involves different types of neural responses. Unimodal tuning to stimulus duration, for example, has been observed in some of these regions, though its presence is either inconsistently reported or appears redundant along the cortical hierarchy. Moreover, how duration tuning supports perception or contributes to different functional outcomes remains largely unexplored. To address these gaps, we measured brain activity using ultra-high-field (7T) functional MRI while participants performed a visual duration discrimination task. Using neuronal-based modeling, we estimated unimodal responses to durations across numerous cortical areas, defined with high anatomical precision. In the parietal and premotor cortices, as well as the caudal supplementary motor area (SMA), we observed neuronal populations tuned to the entire range of presented durations, with a clear topographic organization. In contrast, in the rostral SMA, inferior frontal cortex, and anterior insula, neuronal units showed duration preferences centered around the mean of the presented range. These preferences also correlated with the perceptual boundary that participants used to perform the task. The observed differences in tuning preferences, their spatial clustering, and their behavioral correlations suggest specialized functional roles across cortical regions in temporal processing—from an abstract duration representation for readout and motor-related goals in the parietal and premotor cortices, to a categorical and subjective duration representation 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 areas. Collectively, our findings provide a comprehensive framework of duration processing and perception in vision, highlighting its distributed and hierarchical nature.

Keywords: duration tuning, duration perception, 7T-fMRI, temporal hierarchy