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Title: Decoding eight directions of movement intention with a functional ultrasound brain-machine interface

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Abstract: The posterior parietal cortex (PPC) is an important area for the transformation of visuospatial information into accurate motor planning and execution. PPC sub-regions such as the lateral intraparietal area (LIP) and the parietal reach region (PRR) are especially important for saccades and reaches, respectively. Recently, we showed that functional ultrasound (fUS) neuroimaging can be used to decode the neural correlates of movement planning from PPC – including movement initiation, direction (left/right), and effector (hand/eye) – before movement was executed and with single trial sensitivity (Norman et al., Neuron, 2021). In this study, we extend these results to decode eight directions of eye movements. We used fUS to record changes in cerebral blood volume (CBV) of the PPC in three nonhuman primates as they performed memory-guided eye movements to eight targets throughout their visual field. Using linear decoding methods, we found that we could decode movement intention for these eight directions of movement above chance level (binomial test, $p<0.001$). We then examined the spatial organization of brain activity that maximally discriminates movement direction. We found a continuum, wherein PPC encoded neighboring directions in spatially similar populations of LIP and farther apart directions were encoded by distinct sub-regions within LIP. These mesoscopic maps of movement direction reveal a heterogeneous organization within LIP; small patches of neighboring cortex encode different movement directions. These results address a fundamental gap in our understanding of PPC's functional organization by developing mesoscopic maps of direction specificity previously unattainable with fMRI or electrophysiology methods. These results additionally demonstrate that fUS possesses the spatial and temporal resolution to decode high-dimensional signals that are anatomically entangled within the brain.