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Neural Mechanisms of Dual Motor and Language Processing

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Introduction

While the human cortical grasp network—which includes key regions such as the primary motor cortex (M1), the anterior intraparietal area (AIP) and inferior frontal gyrus (IFG) —has historically been regarded as specialized for motor functions, emerging evidence indicates that it also supports language-related tasks, challenging traditional models of functional specialization. Multiple studies based on intracortical Brain-Machine Interfaces (BMIs) have demonstrated that areas within this network (namely, the motor and premotor cortices) exhibit dual-task representation [1], [2], suggesting that motor and cognitive functions may coexist within overlapping neural populations. However, the neural mechanisms enabling this versatility remain unclear. Additionally, it is unclear whether this versatile functionality generalizes to other regions within this network.

Materials, Methods, and Results

This study focuses on AIP and IFG, two regions classically associated with motor planning and execution. Neural activities were recorded using chronically implanted microelectrodes in a human subject with C3/C4-level AIS B Spinal Cord Injury during experiments involving two tasks: speech motor processing (overt versus covert word enunciation) and motor execution (closed-loop grasp aperture control in a virtual reality environment). Multi-unit neural activities in both regions were analyzed to examine task-specific and shared neural representations. Our results revealed that both AIP and IFG exhibit dual-tuning, allowing them to flexibly encode information for both motor and language tasks as shown by significant cross-validated decoding accuracies. We then explored multiple hypotheses to identify a neural mechanism that best explained the co-existence of information about different tasks within the same neural population. Using a previously developed metric for assessing tuning selectivity[3], we found that dual-task representation in both AIP and IFG was supported by mixed selective (as opposed to task-specialized) neural populations that flexibly reconfigured their functional architecture between tasks. Consequentially, we observed that the low dimensional subspaces within which the two tasks are embedded are not entirely independent, showing a degree of overlap that could represent generalizable patterns between tasks. This cross-task subspace overlap underscores the grasp network's efficient and economic architecture.

Conclusion

This study makes two primary contributions to the understanding of the cortical grasp network. First, it extends previous findings on the network's versatile functionality by demonstrating the multi-functionality of two additional regions, namely, AIP and IFG. Second, it provides novel insights into the functional architecture of the grasp network, uncovering mechanisms that enable neural populations to flexibly represent multiple tasks. These findings fill a critical knowledge gap and lay the groundwork for developing advanced BMIs capable of seamlessly integrating communication and motor functions, meeting the diverse needs of individuals with paralysis.

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