Dysfunctional and compensatory brain network mechanisms underlying math fluency

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Abstract

Poor math fluency (MF), or timed calculation performance, is a prominent cognitive profile of dyscalculia distinct from untimed math performance. Here, we examined the neural substrates related to dysfunctional math fluency and the less understood compensatory neural functions that maintain performance. We performed functional MRI scans of participants with varying MF performance in an event-related paradigm (poor MF, <0.5 accuracy, n = 34, control, accuracy > 0.8, n = 34). Individuals with poor MF showed decreased activation in the intraparietal sulcus (IPS) and decreased striatal to cortical effective connectivity. To examine potential compensatory network function, we studied an independent, well-performing sample (accuracy > 0.8, n = 100) with varying low- and high-IPS activation. We found relatively increased, compensatory, engagement of the angular gyrus, fusiform gyrus, and inferior frontal gyrus in subjects with reduced IPS activation but maintained performance. This was accompanied by increased effective connectivity across these cortical regions, and maintained striatal to cortical effective connectivity. We suggest that these neural network effects could be implicated in compensating for relatively reduced IPS engagement but maintained performance. These variations in functional network engagement, despite reduced IPS activation, may be relevant to identifying strategies for ameliorating MF aspects of dyscalculia and mathematical difficulty.

Significance Statement

Mathematical ability underlies interaction in everyday educational, social, and economic situations, and is one dysfunctional aspect of complex disorders such as schizophrenia. The intraparietal sulcus (IPS) is a fundamental region engaged in numerical processing, but less is known about its interactions with other regions. Here, we suggest a novel compensatory mechanism of cortico-striatal network engagement that maintains numerical cognition in high-performing individuals with relatively low IPS activation, involving the angular gyrus, dorsolateral prefrontal cortex, fusiform gyrus, inferior frontal gyrus, and striatum. This work should stimulate further investigation into the genetic influences underlying these differing brain activation patterns, as well as other areas of cognition where plasticity and compensation may also play important roles.