WHAT DOES “BEING AN EXPERT IN MATHEMATICS” MEAN TO THE BRAIN?

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ABSTRACT

To what extent is varying cognitive expertise reflected in the brain’s functional specificity and connectivity? We addressed this question by examining expertise in mathematics based on the fact that mathematical skills are one of the most critical cognitive abilities known to be a good predictor of academic achievement. We investigated processing of hierarchical structures, which is a fundamental process for building complex cognitive architecture. Experts and nonexperts in mathematics participated in processing hierarchical structures using algebraic expressions. Results showed that a modulating effect depending on expertise was observed specifically in nonexperts in the left inferior frontal gyrus around pars triangularis and frontal sulcus, the left intraparietal sulcus, and the right inferior parietal lobule. This expertise-dependent pattern of activation led to a crucial dissociation within the left prefrontal cortex. More interestingly, task-related functional networks were also modulated differently in the frontoparietal network for relatively good performance and in the frontostriatal network for poor performance. The present study indicates that a high level of expertise is evident in a small number of specific brain regions, whereas a low level of expertise is reflected by broadly distributed brain areas, along with divergent functional connectivity between experts and nonexperts.

INTRODUCTION

In the present study, we investigate the combination of the critical concepts of expertise. We do this by examining the processing of hierarchical structures in the domain of mathematics, testing mathematical experts and nonexperts, and use the domain of language—in which every native speaker should be an expert—as a within subject control. To this end, we measured brain activity associated with the processing of hierarchical sequences in algebraic expressions in mathematical experts and nonexperts, hoping to delineate how varying levels of cognitive expertise modulate functional specificity and connectivity in the brain.

RESULTS

A direct comparison between the groups (experts vs. nonexperts) was performed to assess the influence of mathematical expertise on the modulation of brain activity (Fig. 1), showing more activation in the nonexpert group than in the expert group. We investigated expertise-dependent modulation within the region of interests (ROI) of the prefrontal cortex (PFC) (Fig.
2). We also used psychophysiological interactions (PPI) approach to address the task-based functional connectivity depending on mathematical competence (Fig. 3).

Figure 1. Mathematical hierarchy in nonexperts and correlations with mathematics scores.

Figure 2. Mathematical hierarchy in nonexperts and correlations with mathematics scores.

Figure 3. Task-dependent functional connectivity in nonexperts.
CONCLUSION

Almost from the beginning of modern psychology, researchers have studied individual differences in cognitive functions, providing myriad studies about their roles and implications on cognitive processes at the behavioral level [1]. In the present study, we go beyond this by focusing on the neural level and elucidating how different levels of expertise interchangeably mediate functional specificity and connectivity in the brain. Our data provide evidence for neural efficiency from two aspects. Firstly, the level of individual expertise exerted on neural modulation of cortical and subcortical areas: small and confined activation for the high level of expertise and a broad extent of activation for the low level of expertise. Secondly, divergent brain dynamics between the frontoparietal and frontostriatal networks were recruited depending on the different levels of mathematical competence. Future study should track changes in behavior and brain activity as novice participants gradually become more proficient over time. The present study provides additional knowledge for our understanding of the different neural correlates contingent on individual differences, and the distinctive neural mechanism for optimal cognitive performance in general.

REFERENCES
