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Cognitive resource allocation for neural activity underlying mathematical cognition: a multi-method study.

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Summary: Mathematical cognition requires the allocation of computation resources, where math-specific computations are assumed to take place in the parietal cortex and math-supportive computations in the frontal cortex. Because the pupil dilation has a higher temporal resolution than functional MRI (fMRI), the study investigated to which extent the pupil dilation can help to identify cognitive resource allocation for neural activity underlying math-specific and math-supportive cognition. Combining pupillometry and event-related fMRI, we administered a multiplication verification paradigm to 15 healthy participants asking them to solve easy, moderate, and difficult multiplication tasks. The results revealed that (1) behavioral and pupil dilation data increased parametrically with task difficulty; (2) mental multiplication with increasing difficulty recruited a fronto-parietal circuit comprising left pre-supplementary motor area, left precentral gyrus, right dorsolateral prefrontal cortex, and bilateral intraparietal sulcus (IPS); and (3) pupil dilation was sensitive to cognitive resource allocation for neural activity underlying math-specific cognition in the bilateral IPS, implicating a strong reliance on numerical quantity processing during multiplication. In conclusion, the pupil dilation could be used in mathematics education as an easily acquired peripheral physiological indicator (without relying on fMRI) that might lead to a better understanding of dynamical changes in learning arithmetic abilities as a function of training, experience, and development. On a broader level, its application allows to obtain useful insights into learning disabilities such as dyscalculia, and further improve rehabilitation programs with appropriate intervention structures.

Classification: C30 M60 C80 F20
Keywords: functional magnetic resonance imaging (fMRI); pupil (anatomy); dilation; intraparietal sulcus; dorsolateral prefrontal cortex; cognitive neuroscience; education
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