FMRI Correlates of Mental Attentional Capacity in Children: Data from Moscow Schools

Andrei Faber, Irina Matiulko and Marie Arsalidou

October 21, 2020

fMRI correlates of mental-attentional capacity in children: Data from Moscow schools[1]

Faber A. an6rei.faber@gmail.com, National Research University Higher School of Economics (Russia, Moscow)
Matiulko I. irinamatulko@gmail.com, National Research University Higher School of Economics (Russia, Moscow)
Arsalidou M. marie.arsalidou@gmail.com, National Research University Higher School of Economics, York University (Toronto, Canada)

INTRODUCTION

Academic achievement of school aged children is highly related to core cognitive abilities such as executive function and working memory (Swanson & Alloway, 2012). Although the functional brain correlates of working memory (Owen et al., 2005) and mental-attention (Arsalidou et al., 2013) have been examined previously in adults, little is known about its neural correlates in children. Relation between cognitive performance and brain activity needs investigation with measures having scaled levels of difficulty, for instance, parametric measures of mental attentional capacity (Arsalidou & Im-Bolter, 2017). Mental attentional capacity is the ability to maintain and manipulate information in mind, and can be considered as a maturational component of working memory (Arsalidou et al., 2010). The present study investigates the brain activation to task that measure mental attentional capacity in children using functional magnetic resonance imaging (fMRI).

METHODS

Eighteen children (9-12 years, 10 females) participated in the study. All methods and procedures were approved by the local ethics committee, and parental informed written consent was obtained. MRI acquisition was performed on a 3T Philips scanner. An anatomical T1-weighted image (TR = 2300ms; TE = 2.62ms; 8° Flip angle; 1.0 mm isotropic voxels). Functional images (TR = 2500ms; 115 measurements per run; voxel size = 3.0 mm isotropic; 41 interleaved slices covering the whole brain) were collected while children completed a parametric measure of mental attentional capacity via CMT (Color Matching Task; Arsalidou & Im-Bolter, 2017). CMT task was validated with data from school aged children and adults (Arsalidou et al., 2010; Powell et al., 2014) and integrated well with functional MRI studies (Arsalidou et al., 2013; Vogan et al., 2014, 2018). In this task participants are asked to indicate whether the relevant colors on the screen match those presented in the previous slide. Difficulty of the task increases with the number of relevant colors (n = 1-6). The mental attentional capacity score corresponds to the highest difficulty level passed with at least 70% accuracy (the percentage of correct responses) plus 2 (Arsalidou et al., 2010). Additionally, reaction time was calculated for correct responses for each difficulty level. MRI data preprocessing and analyses were conducted using AFNI (Cox, 1996). Images were first despiked, then slice-time corrected, motion corrected, coregistered, normalized and finally smoothed (with 8mm FWHM Gaussian kernel). Statistical maps were generated for each participant, which represent task-related BOLD signal associated with each difficulty level by subtracting it from the signal associated with control blocks, to yield 6 statistical maps for each participant for each task representing each level of difficulty for each task. ANOVA was calculated to assess the effect of difficulty level on accuracy and reaction time. Whole-brain activity was examined via general linear model (GLM) analyses, which include linear and nonlinear trends performed across comparisons of difficulty levels from 1 to 6 between each other and control items.

---

[1] Funding is gratefully acknowledged from the Russian Science Foundation (#17-18-01047)

RESULTS

A one-way ANOVA was conducted to assess the effect of difficulty level on accuracy. There is a significant main effect of difficulty for the CMT task (F(5,174) = 6.29, $p < 0.001$). Independent pairwise *t*-tests between difficulty levels revealed that each difficulty level had a longer reaction time than the previous one ($p < .0001$), with the exception of the highest level of difficulty ($p < .01$). Before the group GLM analysis, data from individual participants were checked for accuracy, motion artifacts, and structural neurological abnormalities that may affect group statistical results. GLM analysis with linear contrast revealed that as difficulty increased, a parametric increase in activation was observed in insular cortex and brain regions associated with the frontoparietal control network: middle prefrontal cortex, cingulate gyrus, left precentral gyrus, and precuneus. GLM analysis with nonlinear contrast showed that brain activation depends on the difficulty nonlinearly, it increases from level 1 to 3 and decreases from level 4 to 6 in the following brain areas: fusiform gyrus and lingual gyrus.

CONCLUSION

Preliminary results show that children elicit activity in brain areas associated with the executive network that includes prefrontal and parietal cortices. This is consistent with previous results that identified the frontoparietal network in adults (e.g., Owen et al., 2005; Yaple et al., 2019 for meta-analyses). Interestingly, there are neural correlates of mental attention in children that differ from adults such as insular cortex, this finding need a further analysis. Importantly, the current study shows that the relations between cognitive difficulty and brain correlates in children follows a linear trend, at least within the difficulty levels that children can successfully attain.

REFERENCES:

Arsalidou, M., Pascual-Leone J., and Johnson J.. 2010. Misleading cues improve developmental assessment of working memory capacity: the colour matching tasks. *Cogn. Dev.* 25:262–277.

Arsalidou, M., Pascual-Leone, J., Johnson, J., Morris, D., & Taylor, M. (2013). A balancing act of the brain: activations and deactivations driven by cognitive load. *Brain And Behavior*, 3(3), 273-285.

Arsalidou, M., Im-Bolter N. 2017. Why parametric measures are critical for understanding typical and atypical cognitive development. *Brain Imaging And Behavior*, 11(4):1214-1224.

Cox, R. (1996). AFNI: Software for Analysis and Visualization of Functional Magnetic Resonance Neuroimages. *Computers And Biomedical Research*, *29*(3), 162-173.

Owen A. M., McMillan K. M., Laird A. R. & Bullmore E. N-back working memory paradigm: a meta-analysis of normative functional neuroimaging studies. Hum. Brain Mapp. 2005; 25: 46-59.

Swanson, H. L., & Alloway, T. P. (2012). Working memory, learning, and academic achievement. In K. R. Harris, S. Graham, T. Urdan, C. B. McCormick, G. M. Sinatra, & J. Sweller (Eds.), *APA educational psychology handbook, Vol. 1*. Theories, constructs, and critical issues, 327–366.

Vogan, V., Morgan, B., Lee, W., Powell, T., Smith, M., & Taylor, M. (2014). The neural correlates of visuo-spatial working memory in children with autism spectrum disorder: effects of cognitive load. *Journal Of Neurodevelopmental Disorders*, 6(1). Vogan, V., Francis, K., Morgan, B., Smith, M., & Taylor, M. (2018). Load matters: neural correlates of verbal working memory in children with autism spectrum disorder. *Journal Of Neurodevelopmental Disorders*, 10(1).

Yaple, Z., Stevens, W., & Arsalidou, M. (2019). Meta-analyses of the n-back working memory task: fMRI evidence of age-related changes in prefrontal cortex involvement across the adult lifespan. *Neuroimage*, 196, 16-31.