Teasing Apart the Paced Auditory Serial Addition Task (PASAT): An fMRI Study

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Introduction: The PASAT is one of the most widely administered measure of attentional processing for various clinical populations including traumatic brain injury (TBI), multiple sclerosis, systemic lupus erythematosus, and chronic fatigue syndrome. In this test, subjects hear a number-string and add the two most-recently heard numbers. This test has been found to be sensitive to subtle cognitive deficits in mild TBI [1], which has been attributed to its demand on both rapid processing and mental control shifting [2]. There is a growth of research using PASAT in functional neuroimaging studies to examine differences in cortical activations in multiple sclerosis and healthy controls [3-7]. Although areas identified appeared to be related to attention, executive function, and working memory, the specific underlying mechanisms of the cognitive processes involved in PASAT making it a unique task has not been isolated. A PET study [5] administered subcomponents of the PASAT, and found cortical activations consistent with the cognitive elements of auditory perception and processing, speech production, working memory and attention, but no sites were identified for mediating addition. The current study also parsed the PASAT tasks into subcomponents and used fMRI to study the underlying associated cortical networks. We hope with better temporal, spatial resolution and task design, we would be able to improve the mapping of the neural substrates involved.

Methods: 14 healthy right-handed subjects were imaged in a 1.5T scanner while performing the modified PASAT task. The stimuli were presented visually on the screen as well as through an audio system. The paradigm consisted of 3 runs of block design with 3 conditions repeated twice. For all conditions subjects were presented with a number string from 1 to 9, alternating between auditory and visual modalities (see Figure 1 for the 3 conditions with the red arrows indicating correct targets). Each condition lasted for 45s, and each run started with a 15s rest and ended with a 30s rest period to allow for HRF to rise and return to baseline. Rest durations of 15s were inserted between conditions to help with transition. Echo-planar images were collected using a single-shot, blipped gradient-echo echo-planar pulse sequence (TE = 40 ms, TR = 2.5 s, 90 degrees flip angle, FOV = 240 mm, matrix=64x64mm^2). Twenty-two contiguous sagittal 6 mm slices were collected to provide coverage of the entire brain (voxel size 3.75x3.75x6 mm). A total of 156 images were collected per run. High-resolution, three-dimensional SPGR were collected (TE = 5 ms, TR = 24 ms, 40 degrees flip angle, NEX = 1, slice thickness = 1.2 mm, FOV = 24 cm, matrix = 256 x 128) for anatomic localization and co-registration. SPM5 was used for image analysis with conventional preprocessing procedures. General linear model was used to prepare three contrasts of MATH vs MATCH, 1BACK vs MATCH and MATH vs 1BACK. A random effects analysis was performed for the group activation maps for each contrast.

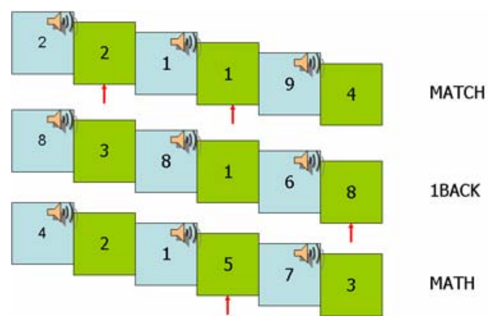

Fig1: Example of the 3 conditions with increasing difficulty: MATCH < 1BACK < MATH

Results: Subjects' performance were above 80% for all conditions and had decreasing accuracy with MATCH > 1BACK > MATH (ANOVA F = 6.986, p<.002) across the 3 conditions. Reaction time differences (ANOVA F = 3.857, p<.029) across the conditions was more subtle with MATH slower than the other two conditions. Figure 2 shows the activation maps of the 3 contrasts: MATH > MATCH contrast represents comparable PASAT condition to previous studies, the MATH > 1BACK condition represents the arithmetic addition component and 1BACK > MATCH represents working memory components.

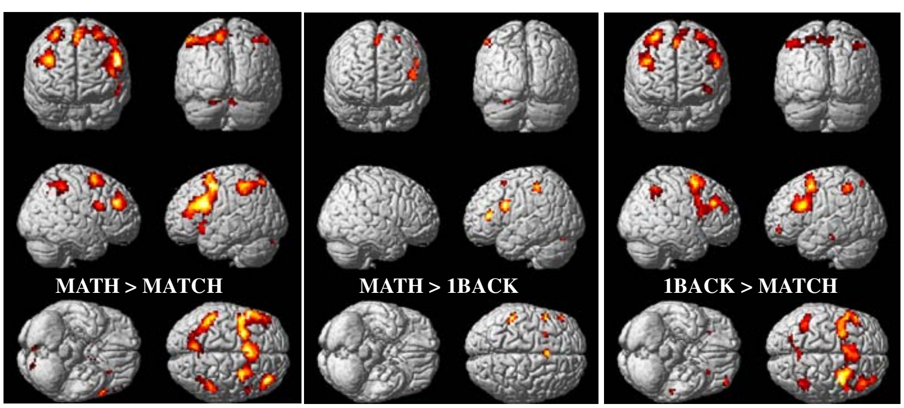

Fig 2 : Activation maps of the 3 contrasts with P<.001 uncorrected.

Conclusion: Consistent with previous studies we found activation in neural networks involved with attention (anterior cingulate and bilateral parietal lobules), and working memory (IFG, IPL and cerebellum). Left lateralized cortical activations thought to be mediating arithmetic addition (left IFG [BA44/9], left inferior parietal lobule [BA40] and left cingulate gyrus [BA32]) were activated. Our modified PASAT paradigm for fMRI appeared to have effectively teased apart the subcomponents of attention, working memory and simple addition. An application of this paradigm to clinical populations could help us to further identify which processes are compromised in that particular population, and thus making the task sensitive to their deficits.

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