Dissociation of transient executive functions from sustained attentional processes in a mixed event-related and block design task.

T. J. Ross[1], Y. Zhang[1], E. A. Stein[1]

[1]Neuroimaging Research Branch, National Instituite on Drug Abuse/NIH/DHHS, Baltimore, MD, United States

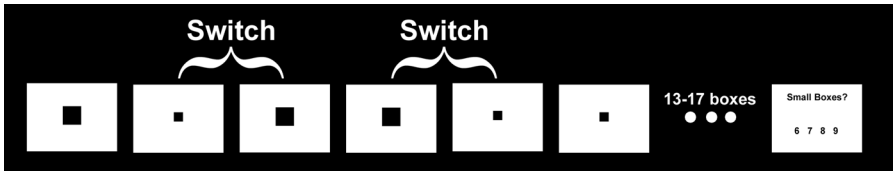
Introduction

The Baddeley model of working memory(1) consists of a governing 'coordinator' called the central executive, responsible for allocating attention resources of two short-term storage systems, the phonological loop and the visuospatial sketchpad. Numerous neuroimaging studies have probed various aspects of this working memory model. However, the recent methodological advance of combining event-related and block features in a single neuroimaging task(2,3,4) allows the parsing of these working memory systems into tonic (block-like) and phasic (event related-like) components. We report results from a new task designed to separate the tonic attentional components from the more phasic executive components via a mixed component design. Subjects were required to maintain two counts simultaneously, with frequent switches occurring between the counts. It has been demonstrated that there is a 'cognitive cost' associated with this switch, putatively mediated by working memory systems.(5)

Methods

23 participants (9 male) were scanned after they gave written informed consent in this NIDA IRB approved protocol. Subjects were normal healthy controls, without neurological disorders, with an average IQ of 114±11, as measured with the WASI, and were an average of 27±7.4 years old at the time of the study. Subjects were scanned twice, separated by about 1 week. Each scan session consisted of two cognitive tasks (only the switching task is reported here), order counterbalanced across subjects, and an anatomical scan for spatial registration/normalization.

The task, illustrated in the first figure, is an event within block task based upon a paradigm previously published by our group(6), with a variable ITI for the switch events utilizing m-sequences.(7) Subjects saw a serial stream of small and large boxes (1900 ms duration, 100 ms ISI) and had to count the number of small boxes and large boxes, frequently switching between the two counts, with a multiple choice response for each count at the end of each block. There were ten ~30 s blocks of task followed by 8 s responding and 4 s feedback, alternating with 30s periods of rest.

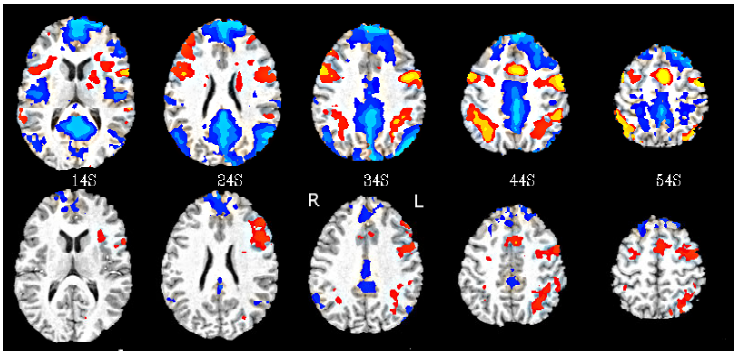


Imaging was performed on a Siemens Allegra 3T scanner, with the following parameters: sagittal EPI, 35 - 4mm slices (whole brain), FOV = 220x220mm, matrix=64x64, TR=2s, TE=27ms, FA=80°.

Analysis was performed in AFNI(8) with the following steps: 1. Motion correction. 2. GLM with regressors for switch events (convolved with hemodynamic model + derivative), a block regressor for tonic activation during the task, and nuisance regressors for responses, feedback and the motion parameters. 3. Spatial normalization to Talairach space and blurring. 4. Voxel-wise repeated measures ANOVA for tonic and switch events. 5. Threshold and cluster mean effects for the block and switch events at a corrected $p<0.05$.

Results

Subjects performed the task at a high level, with an average accuracy of 90±7%. The task activated a heterogeneous network as can be seen in the second figure. The tonic map (top) activated a large, bilateral network including putative attentional and working memory regions. Interestingly there was substantial deactivation, especially notable in the anterior cingulate, extending into medial frontal regions and inferior frontal gyrus, the posterior cingulate, bilateral insula and bilateral middle temporal gyrus. The phasic map (bottom) was left hemisphere dominated and largely overlapped the tonic map, with the notable exception of the left middle front gyrus, which separated itself from the more caudal inferior frontal gyrus activation common to both maps. Minimal deactivation was seen. ANOVA revealed no session effects for accuracy, or for either the tonic or phasic activation maps.



Discussion/Conclusion

By utilizing a mixed event-related and block design task, we were able to demonstrate separate neural networks necessary for the more tonic, attentional compnents vs. the more phasic, executive aspects of a working memory task. The former largely reproduces the results of our prior work(6), with the notable exception of large regions of deactivation. Although it not uncommon to have deactivations in cingulate regions, often attributed to inhibiting ongoing cognitive processes,(9) or inhibition of emotional areas during cognitive task processing,(10) it is as yet unknown why these deactivations are so prominent in this task. For a mixed design task where subjects switched between two semantic categorization tasks, Braver et al(4) also found a largely left-lateralized network associated with switching events between the tasks. There is substantial overlap between 3 of the 5 regions they found and our switching map, i.e.: left dorsolateral prefrontal, left superior parietal and pre supplementary motor area, making these regions likely responsible for executive processing of cognitive switching.

References

1. Baddeley A et al. In: Recent advances in learning and motivation. New York:Academic Press; 1974. p 47-90. 2. Burgund ED et al. Neuroimage 2003;19:29-41. 3. Huettel SA et al. Brain Res 2004;1000:78-84. 4. Braver TS et al. Neuron 2003;39:713-726. 5. Garavan H. Mem Cognit 1998;26:263-276. 6. Garavan H et al. Cerebral Cortex 2000;10:585-92. 7. Buracas GT et al. Neuroimage 2002;16:801-813. 8. Cox RW. Comput Biomed Res 1996;29:162-173. 9. McKiernan KA et al. J Cogn Neurosci 2003;15:394-408. 10. Bush G et al. Trends Cogn Sci 2000;4:215-222.