Kohs' Block Design Task for FMRI: Implemented for naturalistic execution using game control techniques

J. A. Jesberger[1,2], M. Stokes[3], S. Minnes[4], M. Buchner[5], and J. A. Tkach[6,7]
[1]Radiology, Case Western Reserve University, Cleveland, Ohio, United States, [2]Case Center for Imaging Research, Cleveland, Ohio, United States, [3]Case Western Reserve University, [4]Psychology, Case Western Reserve University, [5]Electrical Engineering, Case Western Reserve University, [6]Radiology, Case Western Reserve University, [7]Biomedical Engineering, Case Western Reserve University

Introduction: Selecting tasks for functional neuroimaging and bringing them into the scanner environment without disrupting the image acquisition process is a consistent challenge in fMRI. In this work we selected Kohs' block design task (Figure 1), in which subjects assemble an NxN array of blocks so that the top faces combine to match a target design (1). The goal was to allow the task to be performed by the manipulation and placement of blocks in virtual space using a handheld video gamepad. This work fits within the framework of functional MRI of natural behavior(2).

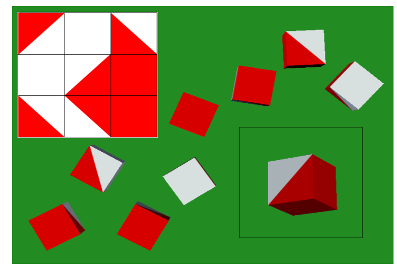

Figure 1. Block Design Task

Methods. A Logitech Dual Action USB gamepad (Logitech International, Apples, Sweden) was modified for MRI compatibility. The software was developed for Windows using Microsoft Visual C# and XNA Game Studio Express 1.0 The program executes three stages: 1) the operator enters session information while the subject executes a controller tutorial, 2) the subject completes a guided practice, and 3) the subject performs alternating epochs of Kohs block designs vs. a control task (visual fixation). FMRI studies were on 3 subjects at 4T (Medspec, Bruker Inc). Five 44sec activation epochs were alternated with six control epochs. Designs of 4 blocks were used. Anatomical (3D T1-W MPRAGE) and BOLD volumes (2D EPI gradient echo, 242 reps, TR 2000ms, TE=22ms, 38 3mm slices 240mm FOV, MTX 64x64) were acquired. Functional maps between the task and control condition were generated in Brain Voyager (Brain Innovation B.V.,Maastricht, the Netherlands) using the univariate general linear model. Head motion, differences in slice scan time acquisition, and temporal linear trends were corrected. Spatial smoothing (Gaussian FWHM= 4mm) was employed and co-registration to the 3D T1W image and spatial normalization to Talairach space completed. Fixed effect group analysis was performed with Bonferroni correction, the group activation map (Figure 2) generated (threshold $Z > 4.9$, $P < 0.05$), and the brain regions recruited by the task identified using the Tailarach Daemon (3).

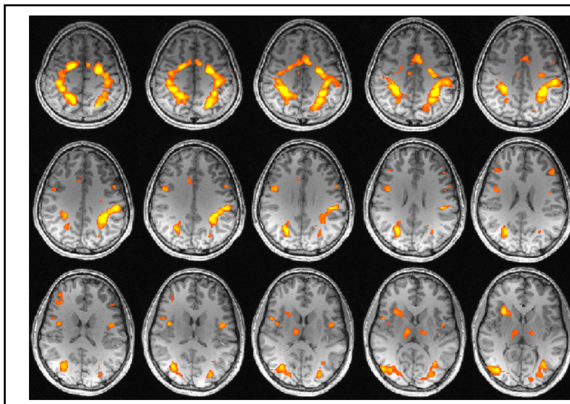

Figure 2. Group activation map in Z scores spatially normalized to Talairach space.

Results. Subjects performed the task readily using the gamepad while lying in the scanner. The gamepad operated normally with no disruptions during rf transmit or gradient switching. Twelve voxel clusters with increased BOLD during block design task were found. Active areas included primary somatosensory (BA 2-3), primary motor (BA 4), and premotor cortices (BA 6), as well as areas contributing to executive function (BA 9-10, 46-47), eye and hand movements (insula), and processing of visual form and motion (BA 21, 37).

Discussion. Visual spatial motor processing lies at the core of our ability to make and use tools, navigate in space, and solve complex physical problems. It represents major part of human intellectual capacity. This task increases our ability to investigate these processes with functional neuroimaging. It meets a criteria (4) that fMRI tasks be "well documented and well established". Activated areas were consistent visual-spatial tasks (5). More importantly, a cognitive model of block design performance defines modifiable task variables that will permit detailed examination of component processes in future studies(6). The gamepad implementation is significant in two respects. It is the standard for current videogames and so familiar to and well practiced by millions, obviating the need for extensive interface training with them, and it supports increasingly complex naturalistic behavior in neuroimaging studies.

References 1. Kohs, S. C. (1923). Intelligence measurement. New York: Macmillian. 2. Mathiak K, Weber R. Hum Brain Mapp. 2006 Dec;27(12):948-56. 3. Lancaster et al. Human Brain Mapping. 2000. 10:120 –131. 4. Savoy RL. Brain Res Bull. 2005 67(5):361-7. 5. Weiss E, et al. Neurosci Lett. 2003 Jul 3;344(3):169-72. 6. Royer FL, Gilmore GC, Gruhn JJ. J Clin Psychol. 1984 Nov;40(6):1474-85