An fMRI-Compatible Writing Device For Investigating the Neural Substrates of Drawing, Copying and Tracing

R. Mraz[1], S. Ferber[2], N. Baker[1], S. J. Graham[1,3]

[1]Imaging Research, Sunnybrook and Women's College Health Sciences Centre, Toronto, Ontario, Canada, [2]Department of Psychology, University of Toronto, Toronto, Ontario, Canada, [3]Department of Medical Biophysics, University of Toronto, Toronto, Ontario, Canada

Introduction

Copying or drawing tasks enjoy popularity in clinical settings because they are easy to administer in a bedside context and they reveal constructional apraxia (inability to assemble the elements of a model object in their correct spatial relationships) in a simple and straightforward way. Constructional skills rely on visuospatial and executive functions and are thus required by many everyday activities. Furthermore, drawing a concrete object is a uniquely human skill which cannot be performed by other primates. Only recently, researchers began to unravel the neural correlates of this mental faculty. In contrast to lesion studies which demonstrated that constructional apraxia is associated with unilateral lesions to either the left or the right parietal lobe, functional brain imaging studies showed a network of mostly bilateral fronto-parietal activation patterns [1,2]. However, all of the previous fMRI studies required subjects to perform the drawing task in a rather unnatural way: subjects were not holding a pen in their hand and they did not receive any visual feedback about their performance. Here we employed a new paradigm which enabled subjects to perform drawing tasks during fMRI in a natural way allowing, for proprioceptive and visual feedback.

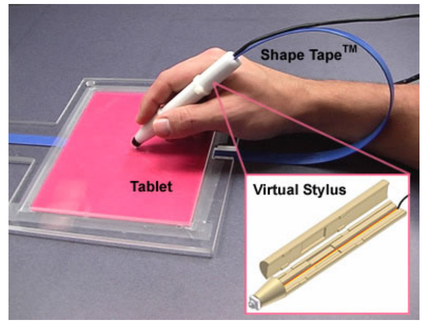

FIG. 1. The Virtual Stylus

Materials and Methods

The virtual stylus (Fig. 1) employed Shape Tape™ technology (Measurand, Inc.) to translate a subject's movements across an acrylic tablet into onscreen cursor movements, visible through fMRI-compatible goggles (Avotec, Inc). Shape Tape™ consists of an array of fibre optic bend and twist sensors which track position and orientation (X, Y, Z, roll, pitch, yaw) along a 96 cm sensitized span. The tape's sensitive region was mounted onto the underside of the tablet with the final 8 cm encased into a plastic stylus. A microswitch on the end of the stylus determined whether or not the tip was in contact with the tablet. The tablet itself rested in an elevated position on the subject's torso while in the magnet bore. A previous study [3] characterized the tape in terms of positional accuracy and thermal drift and concluded that the tape was capable of sub-centimetre accuracy in the given configuration and thus suitable for tasks involving drawing and writing.

The experiment consisted of three tasks: 1) *Draw*, in which subjects were asked to draw a picture of a given word; 2) *Copy*, where subjects copied both standard and nonsensical objects; and 3) *Trace*, where they traced over a playback of a previous drawing. The purpose of the trace task was to elicit the same motor actions as in the draw or copy component but otherwise activating different neuronal regions. Each task was randomly alternated in 30 s blocks with interspersed fixation periods of 30 s. Four runs were conducted, each containing 6 task periods and 6 fixation periods. Six young, healthy subjects were scanned using a GE Signa Eclipse 3.0 T MRI system. Subsequent fMRI data were analyzed using AFNI software.

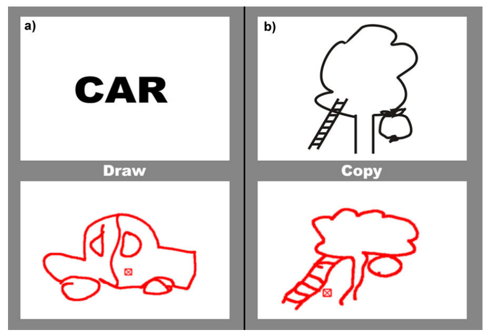

FIG. 2. Representative behavioural results from the **a)** draw task and the **b)** copy task.

Results

After 5 min of training, all subjects claimed general comfort with the device and showed adequate control in performing the various aspects of the experiment. Representative behavioural results (Fig. 2) showed reasonable performance for the various experimental tasks. Head motion was found to be task-correlated for several subjects but in all cases was intra-voxel (< 1 mm in all extents). It is likely that a fixed mounting system, raising the tablet off the subject's torso, would reduce task-correlated head motion further and improve the general ergonomics of the device. Group activation maps (Fig. 3), contrasting periods of stimulus to fixation, show common brain activity in the right cuneus and right middle occipital gyrus, which increased in intensity for the tracing task. As expected, motor regions were activated in all cases; however greater activity was evident in the tracing and drawing tasks, perhaps indicating increased cognitive demand on the visuospatial and motor networks. Noticeable differences included left middle frontal activation during the draw and trace tasks, but not the copy task.

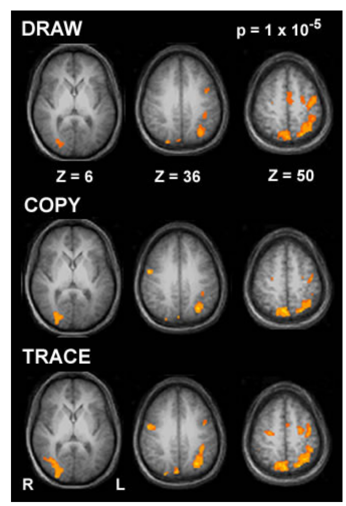

FIG. 3. Group (N=6) activation maps for each of the three tasks. Contrasted versus blank-screen fixation.

Conclusions

The virtual stylus provides an intuitive means for conducting drawing tasks during fMRI. With limited practice subjects displayed reasonable control in using the device for drawing, copying and tracing tasks and could do so without adverse head motion effects. Preliminary results from a simple drawing paradigm show interesting differences in brain activation, especially in frontal and parietal regions. Besides fixing the location of the tablet within the magnet bore, future work will employ the device for more comprehensive drawing studies in order to investigate their links to constructional apraxia.

References

[1] Makuuchi M, Kaminaga T, Sugishita M, Both parietal lobes are involved in drawing: a functional MRI study and implications for constructional apraxia. Cognitive Brain Research 16:338-347, 2003

[2] Ino T, Asada T, Ito J, Kimura T, Fukuyama H, Parieto-frontal networks for clock drawing revealed with fMRI. Neuroscience Research 45:71-77, 2003.

[3] Graham SJ, Mraz R, Tam F, Hong J, Staines WR, McIlroy WE, Zakzanis KK, Integrating Shape Tape With Experiments Involving Virtual Reality and fMRI. Proceedings from the ISMRM 11th Scientific Meeting, 2003.