System for computerized writing and drawing during fMRI

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Writing and drawing are complex, uniquely human behaviours subject to a variety of impediments. Despite the widespread use of writing and drawing in clinical neuropsychological testing, and the importance to our society of writing in particular, few have studied rehabilitation of these behaviours using imaging in patients. Most who have studied writing and drawing using fMRI on healthy participants have done so with writing apparatus unlike real life that produced incomplete records of behaviour: e.g. writing [1] or drawing [2] in the air with a finger; writing or drawing with a real pencil and notepad out of sight in the lap [3]; and tracing a metal groove with a conductive stylus, eyes closed [4].

To enable further study in this area, we designed an fMRI-compatible tablet system that permits more realistic sensory feedback and behavioural logging for a variety of writing and drawing tasks, including a vast number of pen-and-paper neuropsychological tests used widely in the clinic. A device similar in concept has been used in an fMRI study of the Trail Making Test [5], but the new tablet system is based on a touchscreen technology that substantially improves the accuracy and reliability in position measurement compared with the old tablet's fibre optic sensor technology. We tested the new tablet in a preliminary fMRI experiment using a variant of the Trail Making Test.

Methods

Tablet. The tablet consisted of a 5.1 x 3.8 inch (active area) resistive touchscreen sensor panel (Microtouch, Model RES-6.4-PL4, 3M Co., St. Paul, MN) and matching controller board (Microtouch, Model SC4, 3M Co., St. Paul, MN). The touchscreen was non-ferromagnetic, had excellent resolution (0.005 inch) and report rate (180 reports/s), was easily activated by any stylus-like object or body part, and had low cost (< $100 US for panel and controller). The touchscreen panel was mounted on a tilting, height-adjustable stage (Fig. 1) to accommodate users comfortably within the magnet bore while simulating desktop writing. The stylus consisted of a plastic pen barrel with a microswitch on the tip to permit discrete selections, if required. Shielded cables passed the tablet and stylus signals through a filter (56-705-005-LI, Spectrum Control Inc., Fairview, PA) on the magnet room radiofrequency shield penetration panel and then to an interface box containing the touchscreen controller and joystick emulation circuitry for the stylus button. USB cables connected this interface box to the fMRI stimulus computer which displayed task stimuli and feedback via LCD projector. Test fMRI with/without the tablet present in the magnet showed no impact on SNR, stability, or artefact levels.

Task. Two right-handed, young healthy participants (one male), with ethical approval and informed consent, used the stylus to "draw" a line (Fig. 2) joining either spatially scattered numbers in order (1-2-3…; "Trails A") or alternating numbers and letters in order (1-A-2-B…; "Trails B"). Each Trails A or B task lasted 20 s, followed by 20 s of a control task in which participants drew a line from the centre of the display to a circle which would appear at random locations every 2 s. Including 20 s for initial instructions, the total fMRI run length (consisting of the sequence A-Control-B-Control-A-Control-B-Control) was 180 s. Participants completed two such runs in a 3 Tesla MRI scanner (Magnetom Tim Trio, revision VB15A, Siemens, Erlangen, Germany) during BOLD fMRI with gradient-echo echo planar imaging (EPI) (TR/TE/FA = 2000 ms/30 ms/70°, 64x64 matrix, 200 mm FoV, 30 interleaved axial slices, 5 mm thick).

Analysis. Functional MRI data were analyzed using AFNI [6]. Preprocessing included correction for physiological effects using RETROICOR, temporal interpolation for slice-time correction, coregistration to correct for head motion, and spatial smoothing with a 6 mm FWHM Gaussian kernel. Linear regression was performed with a boxcar waveform for each task convolved with a gamma function, as well as a third order polynomial and six motion estimate parameters in the baseline model. The statistical t-map of the Trails B - Trails A contrast was thresholded using a False Discovery Rate method [7] at q=0.001.

Results

Consistent with the major findings of [5], in both participants increased activity for Trails B versus Trails A was widespread, and included middle frontal gyrus, precentral gyrus, superior frontal gyrus, medial frontal gyrus, insula, middle temporal gyrus, and superior temporal gyrus. Representative results are shown in Fig. 3. However, compared with [5], increases were not as lateralized to the left side, and the middle temporal and middle frontal activation was stronger. Head motion for both participants was below 1 mm and neither reported problems using the tablet.

Discussion

We developed a tablet for fMRI of writing and drawing tasks that is accurate, reliable, requires infrequent calibration, and is relatively inexpensive. In an example experiment, we imaged the neural substrates of a widely used neuropsychological test, with major results that are comparable to a previous group study. Aside from the differing statistical thresholds and numbers of participants, some of the differences in observed activation may have been due to minor but nevertheless noticeable accuracy and reliability problems with the previous study's tablet which are not present in the new tablet. We plan to extend the present work to a larger group as part of a study involving a battery of neuropsychological tests currently under development.

1. Katanoda et al. *Hum. Brain Map.* **13**, 34-42 (2001). ● 2. Makuuchi et al. *Cogn. Brain Res.* **16**, 338-347 (2003). ● 3. Harrington et al. *Hum. Brain Map.* **28**, 450-459 (2007). ● 4. Reithler et al. *J. Neurosci. Met.* **152**, 10-17 (2006). ● 5. Zakzanis, et al. *Neuropsychologia.* **43**, 1878-1886 (2005). ● 6. Cox. *Comp. & Biomed. Res.* **29**, 162-173 (1996). ● 7. Genovese, et al. *NeuroImage.* **15**, 870-878 (2002).

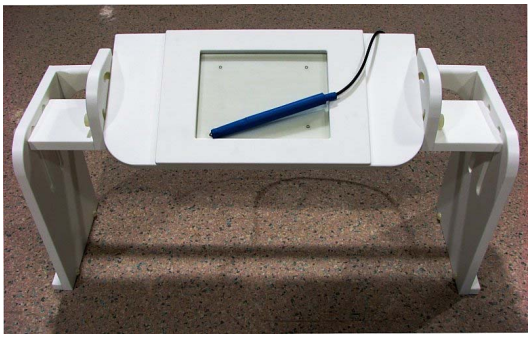

Fig. 1. Tablet with adjustable stand and stylus.

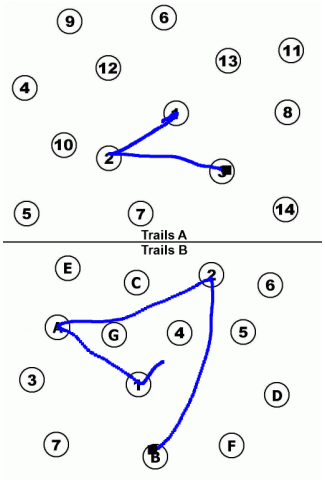

Fig. 2. Trails A and B tasks.

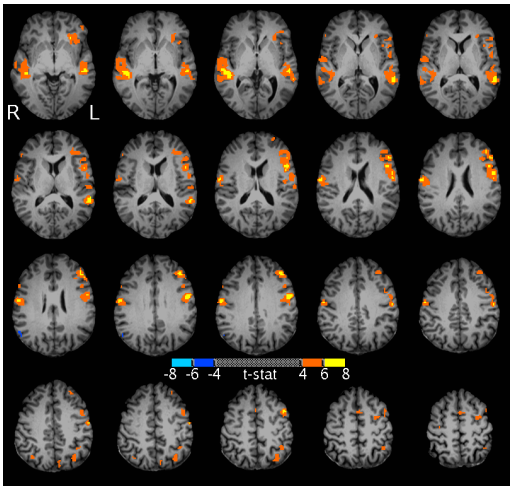

Fig. 3. Trails B – Trails A contrast t-map (Participant 1).