Developmental Coordination Disorder: A Voxel-Based MRI Study of Neural Correlates

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INTRODUCTION

Developmental Coordination Disorder (DCD) is a common childhood disease, affecting roughly 5-6% of all school-aged children [1], characterised by deficits in learning and automating motor skills [2]. It can have a significant long-term social and academic impact on sufferers [3]. The role of specific brain areas in DCD has long been postulated from psychometric studies, with particular evidence for the cerebellum [4] and parietal lobe [5] amongst others. However, the underlying aetiology of the disease remains poorly understood. Most studies of DCD have been restricted to behavioural or physiologic measurements; there are no existing structural imaging studies of DCD. This study is, to the best of our knowledge, the first to use structural magnetic resonance imaging to investigate the hypothesis that DCD has neural correlates that can be seen in brain morphometry.

METHODS

The study involved 14 boys (age range: 8.5-12.9 years) who met the clinical criteria for DCD assessed using the Movement Assessment Battery for Children (Movement-ABC) [6]. Average total Movement-ABC score for the group was 10.7 (range 4.5 - 14). Imaging was performed on a 3T MR scanner (Philips Achieva X-Series). A 3-D data set was acquired for each subject using a T1-weighted TFE sequence (TR=9.7s, TE=4s, TI=600ms, NEX=1, flip angle 12°, matrix 256 x 256 x 160, FOV 256 x 256 mm^2, voxels 1 x 1 x 1 mm^3). Two psychometric measures were taken as the overall score from self-reporting questionnaires: the Movement-ABC and the Aberdeen Motor Development Questionnaire (AMDQ). A separate specific motor skill test involved a figure-of-8 tracing task [7]. A number of spatial response parameters were recorded, including measures of: root mean square error ('RMS error'), i.e. a measure of average distance between correct and actual position; standard deviation of the error ('STD error'), i.e. measure of variation of the distance between correct and actual position; x-axis gain ('x-gain') and y-axis gain ('y-gain'), which is the difference in frequency of moving dot and frequency of participant's movement in the x-axis and y-axis respectively. Whole brain voxel-based analysis was performed using SPM8 (http://www.fil.ion.ucl.ac.uk/spm/). Images were segmented into grey and white matter maps [8]. The segments were warped to the space of the average of all the subjects using DARTEL [9]. The output images were scaled to preserve volume, re-sampled to 1.5mm isotropic voxels and smoothed with an 8mm FWHM isotropic Gaussian kernel. Linear regressions of the measured signal on the psychometric data were performed. In all cases p values less than 0.05 were considered statistically significant. Voxel-wise testing correction was made for multiple comparisons by controlling the family-wise error (FWE) rate and further Bonferroni corrected for multiple hypotheses.

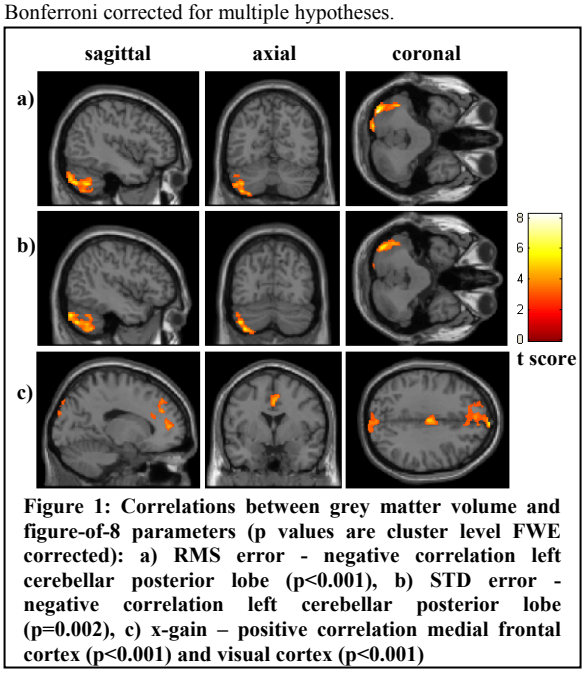

Figure 1: Correlations between grey matter volume and figure-of-8 parameters (p values are cluster level FWE corrected): a) RMS error - negative correlation left cerebellar posterior lobe (p<0.001), b) STD error - negative correlation left cerebellar posterior lobe (p=0.002), c) x-gain – positive correlation medial frontal cortex (p<0.001) and visual cortex (p<0.001)

RESULTS

From the figure-of-8 parameters, a negative correlation between relative regional GM volume and RMS error was seen in the left cerebellar posterior lobe. Significant positive correlations were seen with x-gain in left frontal lobe and left occipital lobe. There was a trend level negative correlation STD error in the left cerebellar posterior lobe. Correlating Movement-ABC overall scores with GM volume showed a positive correlation at trend level in the left parahippocampal gyrus. There were no correlations found at either significance or trend level for AMDQ scores. There were no significant or trend-level correlations between regional WM volumes and any of the psychometric measures.

DISCUSSION

Both the Movement-ABC and AMDQ questionnaires score based on performance in a wide range of motor skills. It is possible that it is this lack of specificity, and the heterogeneous nature of DCD, that gives a lack of significant correlations in localised brain regions for these measures. The figure-of-8 tracing parameters allow for more specific analysis of a particular skilled motor task. The significant correlation between GM volume and RMS error scores in the left cerebellar posterior lobe is suggestive of the role of the cerebellum in DCD. The similar pattern at trend-level for STD error provides additional evidence of this. x-gain is a measure of error in movement in the x-direction, reflecting the percentage of time the participant's movement is not at the same frequency as the moving dot. Any corrective movement, by definition, must be at a different speed/direction to the moving dot. As such we assume that x-gain reflects the amount of movement correction. The results show a clear distinction between neural correlates of general position accuracy given by RMS error and the x-gain frequency error. The medial frontal cortex (MFC) is known to be involved in representation of action [10]. The correlation seen here between the x-gain parameter and GM volume provides some evidence that the MFC is important for action monitoring and correction, and is distinct from the cerebellar role in accuracy and precision. This study provides the first neuroimaging evidence that regional grey matter structure plays a role in DCD. This study has looked at neuro-correlates of motor skill within a DCD population. Results suggest grey matter volumes in specific brain areas are correlated with performances in motor tasks within the DCD population. To increase our understanding of the nature of DCD, further studies are required to compare between groups of DCD and typically developing children.

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ACKNOWLEDGEMENTS

Supported in part by the Northwood Trust and SINAPSE