Group Differences in Brain Activity between Dyslexic Children and Normal Controls Using Functional Magnetic Resonance Imaging

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Introduction: Dyslexia is referred to as specific reading retardation/disability despite conventional instruction and adequate intelligence. 5-10% of children in 1st through 5th grades are reported to have developmental dyslexia in the United States [1]. Reading skill is very important for children to acquire in early education. We compared brain activation of children with dyslexia to normal controls for reading and action-related task using function magnetic resonance imaging (fMRI) and data-driven independent component analysis (ICA) [2].

Materials and Methods: This study was IRB approved and HIPAA compliant. Right-handed English-speaking 28 children (11 control and 17 dyslexic subjects) of 6-15 years (mean 10±2.8 years) at the time of imaging underwent this investigation. Both groups were matched in age, gender, and education level. Participants were presented with several letters (one at a time) and were instructed to read and to press a button held in their right hand if they saw tall letters, for example, b, d, h, etc, or a button held in their left hand if they did not . Each letter, reading, and action tasks were performed in a block design with 42s intervals of stimulus presentation interleaved with 16.8s rest intervals. The paradigm used in this study was same as that described in ref #3. FMRI was performed at 3T (Philips Health Systems, Cleveland, OH, USA) using an 8-channel head coil with EPI, TR/TE=2sec/30ms, FA=90°, FOV=19.2×19.2cm^2, matrix size=128×128, thickness=2.8mm, no gap, and 50 slices. Anatomical images were acquired using 3D-FFE sequence (TR/TE=9.8ms/4.6ms, matrix size=256×256, and no gap). Slice timing and motion corrections for pre-processing were done using SPM5. The functional MR images were first co-registered to the high resolution anatomical images and then normalized to the Montreal Neurological Institute (MNI) space. The normalized functional images were spatially smoothed with a 6 mm FWHM Gaussian kernel. Spatial independent component analysis (ICA) with temporal concatenation was performed using the group ICA of fMRI toolbox (GIFT) v1.3h (http://mialab.mrn.org/software/). Automatic dimensionality estimation using minimum description length resulted in 31 independent components. For fMRI data within-group analysis, contrast images from the analysis of individual subject were analyzed by using one-sample t-test to allow inference to the general population with threshold at p<0.05, family wise error (FEW) corrected for multiple comparisons across the whole brain. To make direct comparison of brain activations between controls and dyslexic subjects, contrast images for the main effects were evaluated using a two-sample t-test with threshold at uncorrected p<0.001.

Results: The group differences in brain activities between dyslexic children and normal controls are shown in occipital lobe in Fig.1 (a); parietal lobe in (b); temporal lobe in (c); Broca's area in (d); frontal lobe in (e)-(f) where hot red color represents remarkable difference between the 2 groups. The anatomical differences in brain activities between the 2 groups using the two sample t-test are summarized in Table 1.

Table 1 The summary of brain activity differences between controls and subjects with dyslexia: controls > patients
(L = left, R = right, B = bilaterally, BA = Broadmann area, and SC = size of clusters)

Region	L/R/B	BA	MNI coordinate	t-score	SC
Visual cortex	B	17, 18	-6, -68, 10 & 18, -70, 0	5.16	53
Secondary visual cortex	B	19	22, -92, 24 & -44, -50, -22	4.88	50
Auditory cortex	B	41, 42	58, 12, 0 & -60, -18, -8	5.01	75
Prefrontal cortex	R	10	40, 46, -2	5.13	36
Middle frontal cortex	B	9	-8, 38, 40 & 36, 30, 34	5.87	56
Inferior frontal cortex	R	11	20, 10, -16	4.87	27
Motor cortex	B	4, 6	46, 8, 28 & -6, 38, 50	5.15	39
Sensory cortex	B	7	-10, -28, 56 & 20, -26, 50	5.01	36
Broca's area	L	44, 45	-46, 24, -14	5.08	26
Posterior cingulated cortex	L	23	-14, -26, 42	4.55	33
Anterior cingulated cortex	L	24	-6, 16, 40	4.28	31
Posterior temporal lobe	L	38	-48, -50, 10	5.38	53

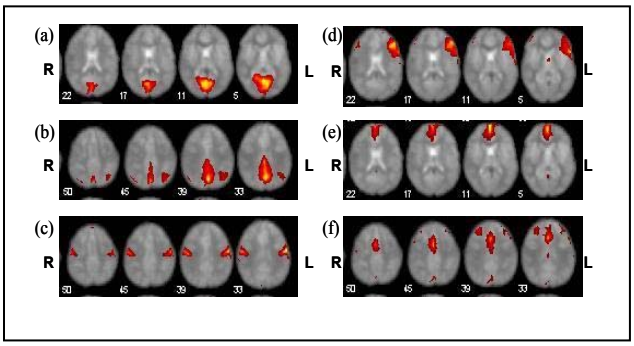

Fig.1 The group difference in brain activities between dyslexic children and normal controls are shown using a two sample t-test with threshold at uncorrected p<0.001 (controls > patients: R = right, and L = left).

Conclusions: In this study, we demonstrated there are group differences in brain function activities in visual, auditory, motor, executive, sensory cortexes, and Broca's area between dyslexic children and normal controls using reading and action-related task fMRI and group ICA. Our findings show there are activity differences in the left inferior frontal gyri and superior temporal sulcus between the 2 groups [3, 4] and also could be an indicator of study of subjects with dyslexia.

References: [1] Shaywitz et al., New England Journal of medicine 1992; 326: pp145; [2] Calhoun et al., Hum Brain Mapp 2001; 14: pp140; [3] Turkeltaub et al., nature neuroscience 2003; 6(6); pp767; [4] Wagner et al., Psychol Bull 1987; 101: pp192.