STATIC AND DYNAMIC VISUOMOTOR TASK PERFORMANCE IN CHILDREN WITH TRAUMATIC BRAIN INJURY: A DIFFUSION TENSOR IMAGING STUDY

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Background and objectives: The most frequent cause of disability and death in children and adolescents is traumatic brain injury (TBI), often due to traffic accidents [1-2]. TBI children incur deficits in memory, attention, language, problem solving, and academic skills. Moreover, motor performance is impaired for years following the insult and specific deficits are often reported. Deficits in eye-hand coordination require careful attention during rehabilitation, even in the chronic phase after brain damage, because for many activities of daily living, eye-hand coordination is of great importance. The cerebral structures concerned with the control of tracking are well mapped and form extensive and highly complex functional entities, incorporating cortical and subcortical structures as well as the cerebellum. These complex anatomical structures are highly susceptible to the adverse effects of brain injury [3]. The aim of the present study was to examine long term effects of TBI on static and dynamic visuomotor task performance on a relatively easy task with increasing difficulty, and to test whether deficits in visuomotor performance are related to variation in structural properties of the motor white matter pathways.

Methods: Nine children with TBI and 17 controls (aged 9-17 y) performed two visuomotor tasks that differed in degree of time that is available for information processing required for successful performance. In the static visuomotor task, a computerized version of the flower trail task of the Movement Assessment Battery for Children was used (MABC). Children traced a flower (Figure 1) as accurately as possible with an electronic pen on a digitising tablet and without speed constraints. The task tested the ability to adapt movement accuracy to spatial constraints, based on incoming visual feedback without temporal pressure. The dynamic task required faster perceptual information processing and predictive movement control. The children were instructed to manually track a visible, accelerating target consisting of a circular configuration (Figure 1). The target accelerated when it was tracked successfully; otherwise it decelerated to allow re-entry. Depending on its velocity, performance was increasingly based on prospective (predictive) control. The children were scanned using DTI along with standard anatomical scans. The DTI images were acquired on a 3T scanner (Intera, Philips) using a DTI SE-EPI (diffusion weighted single shot spin-echo echoplanar imaging) sequence (TR/TE 7916/68 ms; matrix 112×112; FOV 220×220 mm^2; parallel imaging factor 2.5; 68 contiguous sagittal slices; slice thickness 2.2 mm; voxel size 2×2×2.2 mm). Diffusion sensitizing gradients were applied at a b-value of 800 s/mm^2, along 45 non-collinear directions with one b0 image. A T1-weighted coronal 3D-TFE (182 contiguous coronal slices; FOV 250 mm; TR/TE 9.7/4.6 ms; slice thickness 1.2 mm; matrix 256×256; voxel size 0.98×0.98×1.2 mm) was acquired for anatomical reference. The DTI data were analyzed and processed in ExploreDTI, using the following multi-step-procedure: (a) Subject motion and eddy-current induced geometrical distortions were corrected for [4]. (b) The diffusion tensors and subsequently the FA, MD, and axial and radial diffusivity were calculated using a non-linear regression procedure [5]. (c) The DTI data were coregistered (full affine: 12 df) to the FA template in MNI space [6]. (d) A standard deterministic streamline fiber tractography approach was used, as described in Basser et al [7]. (e) The probabilistic cytoarchitectonic atlas developed by Eickhoff et al [8], and mapped in MNI space as provided by the FSL toolbox (http://www.fmrib.ox.ac.uk/fsl/), was used to perform the correlation analysis. For the flower, pursuit measures, and DTI measures, non-parametric Mann-Whitney U-tests were performed for comparing the group of children with TBI with the age- and gender matched control group.

Results: On the flower trail tracing task, with only spatial constraints, performance of children with TBI was comparable to the control children. Only for the number of times that the pen tip crossed a solid line of the flower, a marginally significant effect of group was found. In contrast, children with TBI showed clear problems in performing the tracking task, in which both spatial and temporal constraints had to be dealt with (as shown in Table 1). For example, the children with TBI kept the cursor within the target for a shorter duration, Z = -2.70, p = .007. In the TBI group, reductions in both anisotropy and coherence of fiber tract organization were noted in the corpus callosum, right cerebral peduncle and left anterior corona radiate (Figure 2). Preliminary results suggest that the motor deficits correspond well with reductions in anisotropy, for example, 'number of circles' was significantly related to mean FA in left corticospinal tract fibers (r = .74) and the right (r = .83) and left (r = .76) superior cerebellar peduncles.

Conclusions: This study supports the view that conventional quantitative computerized assessment of visuomotor performance might have considerable potential to contribute to improved assessment of children with TBI. This study provides further evidence that DTI may help in understanding the neural basis of motor performance deficits when quantitative measures of tissue damage are correlated with appropriate behavioural measurements.

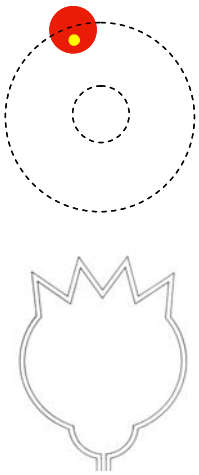

Figure 1

	Control Mean (SD)	TBI Mean (SD)	p-value
Flower trail			
# Errors	0.5 (0.7)	1.0 (1.0)	.05
Movement time (s)	37.0 (11.9)	38.4 (15.4)	.91
Mean velocity while moving (cm/s)	1.4 (0.2)	1.4 (0.3)	.69
# Velocity peaks/s	3.5 (0.9)	3.5 (1.3)	.83
Trajectory length (cm)	31.5 (2.6)	30.6 (3.4)	.14
Mean axial pen force while moving (N)	2.00 (0.73)	1.95 (0.65)	.71
Visuomanual pursuit			
# Circles	20.5 (4.4)	18.1 (5.8)	.10
Max. target velocity (cm/s)	12.5 (2.8)	11.1 (3.9)	.11
Duration in target (s)	50.3 (0.9)	49.3 (1.5)	.01
Median distance between centres (cm)	0.57 (0.05)	0.59 (0.05)	.03
SD of distance between centres (cm)	0.45 (0.13)	0.55 (0.38)	.02
# Velocity peaks/cm when in target	0.54 (0.22)	0.73 (0.30)	.02
# Stops	21.1 (12.5)	25.5 (11.3)	.03
Median duration of stops (ms)	82.7 (9.3)	86.7 (17.0)	.65
Mean axial pen force (N) when in target	0.87 (0.54)	1.19 (0.64)	.10

Table 1

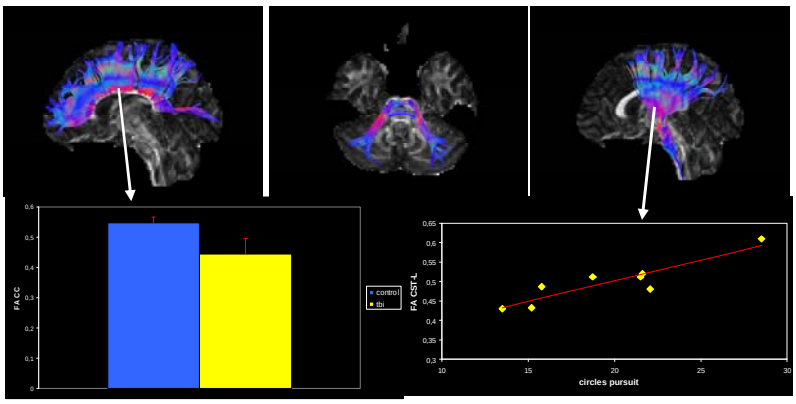

Figure 2

References: [1]J.F. Kraus & D.L. McArthur, Neurol Clin, 14: 435-50,1996; [2]D.M. Sosin et al, Brain Inj, 10: 47-54, 1991;.[3]B.J. He et al, Curr Opin Neurol, 20:655-60, 2007;.[4] G.K. Rohde et al, Magn Reson Med, 51:103-14, 2004; [5] D.K. Jones & P.J.Basser, Magn Reson Med, 52:979-93, 2004; [6] S. Mori et al., NeuroImage, 40, 570-82, 2008; [7]P.J. Basser et al, MRM, 44:625-32, 2000; [8]S.B. Eickhoff et al, Neuroimage, 25:1325-35, 2005.